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MAY 2 9 1998

The Honorable Philip R. Recht
Deputy Administrator
NATIONAL HIGHWAY TRAFFIC
SAFETY ADMINISTRATION
400 Seventh Street, S.W., Room 5220
Washington, DC 20590

Dear Mr. Recht:

Re: **Settlement Agreement**
Progress Report For Year 3, Second Quarter

Enclosed are the "Progress Report For Year 3, Second Quarter (July 1, 1997-September 30, 1997)" and the financial reports for the second quarter of year 3.

Sincerely,

David A. Collins
Attorney

c: James A. Durkin, Esq.

Enclosures

PROGRESS REPORT
For Year 3, Second Quarter
(July 1, 1997 - September 30, 1997)

This is the second quarterly report for year 3 submitted to the National Highway Traffic Safety Administration (NHTSA) by General Motors Corporation (GM) relating to the status of the research projects which have been established pursuant to the terms of the Settlement Agreement between the U.S. Department of Transportation and General Motors Corporation, dated March 7, 1995. This report summarizes the progress made on research projects in five different research areas, during the period July 1, 1997 through September 30, 1997.

For some of the research projects, the progress reported involves tasks that were described in statements of work that were approved by NHTSA for year 3 of the settlement agreement and which are being supported with funds expended by GM in year 3. For others, the progress reported involves tasks that were described in statements of work that were approved by NHTSA for year 2, and the work is continuing into year 3 of the settlement agreement with funds expended by GM in year 2.

I.B. Fire Safety Research

Project B. I: Analysis of Motor Vehicle Accident Data

Accident data reports and data analyses related to collision fires and to a secondary concern, non-collisionfires, will be reviewed to develop an analytical agenda to identify additional areas in which to focus. Based on the analytical agenda, national (i.e., FARS and NASS) and state vehicle databases will be analyzed and compared in studying the causes and effects of both collision and non-collision fires. This project will also examine questions of data quality and completeness concerning motor vehicle fires and recommend revisions and enhancements to data collections as appropriate to assist safety researchers in studies of motor vehicle fires.

Sub-Project B. 1 (a): This sub-project was completed and the final report was submitted to NHTSA in year 2 of the settlement agreement.

Sub-Project B.1(b): FARS Multiple Cause of Death (MCOD) Injury Analysis Study (collision fires).

Dr. Lindsay I. Griffin, III of the Texas Transportation Institute (TTI), Texas A&M University, is the principal investigator for this sub-project.

During the second quarter of year 3, TTI continued to collect the requisite traffic crash data to perform the analyses envisioned in the statement of work.

A draft report was developed and the review process within GM was initiated during the second quarter of year 3. This draft report documents some serious inconsistencies in the "fire data" in FARS as illustrated in the following tables.

Percent of Passenger Cars and Light Trucks Involved in Fatal Crashes that Experienced a Fire (FARS 1987-1989)		
Utah (low)	1/888	0.11%
Hawaii (high)	23/434	5.30%

Of those Passengers Cars and Light Trucks that Experienced Fires, the Percent for Which "Fire or Explosion" was the Most Harmful Event (FARS 1987-1989)		
Illinois (low)	1/180	0.56%
Virginia (high)	47/49	95.92%

Moreover, of the 1,785 fatally-injured vehicle occupants considered in the study who sustained "fire-related" injuries, 201 (11.26%) were riding in vehicles that did not experience fire.

The draft report suggests some constructive steps that might be taken to improve the reliability of the FARS database with respect to the fire data that it contains.

Further analyses are now underway to compare the 1994-1996 FARS data to the data from 1987-1989 that have already been looked at in some detail. These new analyses further support the notion that the variable "most harmful event" is not a reliable measure of the consequences of a "fire or explosion" in a vehicle. Some states (e.g., California) show comparable percents of fire or explosion as MHE in 1987-1989 and 1994-1996; most do not (e.g. Texas, Florida, North Carolina). (See the following table).

Based on the reliability assessments performed, Dr. Griffin does not have sufficient confidence in "most harmful event" in FARS, as he believes it is not reliable for purposes of studying vehicle fires. Future analyses undertaken in this project to study motor vehicle fires will not use MHE as a predictor or controlling variable.

Percent Fire/Explosion as Most Harmful Event in 1987-1989 and 1994-1996, by State:

STATE	1987 - 1989 FIRE	OTHER	TOTAL	PERCENT	1994 -- 1996 FIRE	OTHER	TOTAL	PERCENT
ALABAMA	22	70	92	23.91	31	46	77	40.26
ALASKA	0	4	4	0.00	0	8	8	0.00
ARIZONA	24	30	54	44.44	24	77	101	23.76
ARKANSAS	40	50	90	44.44	23	58	81	28.40
CALIFORNIA	230	345	575	40.00	164	245	409	40.10
COLORADO	9	28	37	24.32	11	25	36	30.56
CONNECTICUT	8	46	54	14.81	0	25	25	0.00
DELAWARE	2	13	15	13.33	0	11	11	0.00
DIST OF COLUMBIA	0	4	4	0.00	1	2	3	33.33
FLORIDA	24	107	131	18.32	54	57	111	48.65
GEORGIA	27	138	165	16.36	7	144	151	4.64
HAWAII	4	19	23	17.39	1	5	6	16.67
IDAHO	3	6	9	33.33	5	4	9	55.56
ILLINOIS	1	179	180	0.56	11	163	174	6.32
INDIANA	44	68	112	39.29	25	122	147	17.01
IOWA	14	65	79	17.72	0	35	35	0.00
KANSAS	2	41	43	4.65	1	44	45	2.22
KENTUCKY	13	86	99	13.13	24	63	87	27.59
LOUISIANA	36	63	99	36.36	55	20	75	73.33
MAINE	7	6	13	53.85	8	4	12	66.67
MARYLAND	23	24	47	48.94	19	8	27	70.37
MASSACHUSETTS	14	67	81	17.28	3	43	46	6.52
MICHIGAN	15	146	161	9.32	25	79	104	24.04
MINNESOTA	13	80	93	13.98	7	58	65	10.77
MISSISSIPPI	2	27	29	6.90	9	12	21	42.86
MISSOURI	84	41	125	67.20	56	77	133	42.11
MONTANA	10	5	15	66.67	0	7	7	0.00
NEBRASKA	7	13	20	35.00	17	6	23	73.91
NEVADA	6	16	22	27.27	0	27	27	0.00
NEW HAMPSHIRE	1	14	15	6.67	2	8	10	20.00
NEW JERSEY	3	48	51	5.88	14	32	46	30.43
NEW MEXICO	5	18	23	21.74	4	9	13	30.77
NEW YORK	45	78	123	36.59	50	51	101	49.50
NORTH CAROLINA	36	55	91	39.56	8	152	160	5.00
NORTH DAKOTA	1	3	4	25.00	2	10	12	16.67
OHIO	3	161	164	1.83	8	188	196	4.08
OKLAHOMA	3	87	90	3.33	1	95	96	1.04
OREGON	17	66	83	20.48	12	65	77	15.58
PENNSYLVANIA	48	123	171	28.07	35	90	125	28.00
RHODE ISLAND	0	8	8	0.00	0	3	3	0.00
SOUTH CAROLINA	40	4	44	90.91	50	0	50	100.00
SOUTH DAKOTA	1	13	14	7.14	2	15	17	11.76
TENNESSEE	65	55	120	54.17	42	78	120	35.00
TEXAS	151	97	248	60.89	79	159	238	33.19
UTAH	1	0	1	100.00	0	3	3	0.00
VERMONT	0	9	9	0.00	4	8	12	33.33
VIRGINIA	47	2	49	95.92	3	34	37	8.11
WASHINGTON	15	40	55	27.27	9	44	53	16.98
WEST VIRGINIA	12	22	34	35.29	7	25	32	21.88
WISCONSIN	29	61	90	32.22	14	73	87	16.09
WYOMING	0	5	5	0.00	0	8	8	0.00
	1207	2756	3963		927	2625	3552	

Sub-Project B.1 (c): Exploratory Analysis of NFIRS Database (collision and non-collision fires)

Dr. Lindsay I. Griffin, III of the Texas Transportation Institute (TTI), Texas A&M University, is the principal investigator for this sub-project.

During the second quarter of year 3, no work was done on the National Fire Incident Reporting System (NFIRS) database.

Sub-Project B.1 (d): Analysis of CODES Database (collision fires)

Dr. Lindsay I. Griffin, III of the Texas Transportation Institute (TTI), Texas A&M University, is the principal investigator for this sub-project.

TTI continues to have difficulty obtaining the data they would like to have for this project. For example:

- In April the North Carolina Division of Motor Vehicles agreed that the Highway Safety Research Center of the University of North Carolina could sell TTI several years of crash data. In spite of repeated assurances that the data would be forthcoming, the data have not yet been received.

- TTI has been working through the Centers for Disease Control in Atlanta to identify the names of 128 decedents who were killed in vehicles that experienced fire and who were autopsied in Cook County, Illinois. TTI was led to believe that Cook County would cooperate with its request for copies of investigations, autopsies, and toxicological reports. But, at the last minute, the Chief Medical Examiner chose not to cooperate.

- The Medical Examiners Office in Harris County, Texas has provided TTI with investigations, autopsies, and toxicological reports on 49 decedents who were killed in vehicles that experienced fires. Unfortunately, Dallas County has still not provided a comparable set of data in spite of numerous requests.

- Utah has provided TTI with four additional years of CODES data. Unfortunately, when TTI began working with the data, they found that the data that were provided were erroneous, (e.g., crash years out of range). Utah is working to provide TTI with new data sets.

- Finally, the North Carolina Division of Motor Vehicles has provided TTI with hard copies of crash reports on 103 fatal, fire-related crashes in North Carolina in 1995 and 1996. From these hard copies, TTI will supply the names of the decedents in these crashes (and the dates of their deaths) to the Medical Examiners office in Chapel Hill and, through their assistance, collect the investigation, autopsy, and toxicological reports required for subsequent analyses.

Project B.2: Case Studies of Motor Vehicle Fires

In-depth investigations of vehicle fires will be conducted in multiple U.S. and Canadian jurisdictions. It is intended that the multiple jurisdictions include the trauma center locations selectedfor the Burn and Trauma Research Projects. Investigations will include: accident circumstances, vehicle and scene inspections, detailed accident reconstruction, injury inventory, injury treatment, treatment outcome and treatment costs. The manner of collecting, storing and retrieving this data should be developed so as to be compatible with the automated data processing system for the trauma centers network (see E. 3. Establish a Networkfor Data Collection on Crashes, Injuries, and Their Consequences) and the electronic database with images for the NASS Crashworthiness Data System (CDS) Training sessions and materials prepared for this project will be made available to NASS investigators.

Sub-Project B.2 (a) Development of Systems

The University of Washington Transportation Center (TRAC) is the contractor for this project. Leland E. Shields is the principal investigator.

Under this project, TRAC will conduct in-depth investigations of 50 collision-fire incidents including on-site inspections of scenes and vehicles, accident reconstructions and determinations of fire causation. Also included will be medical analysis of the cause(s) of injuries. The sample of 50 incidents will not be a statistically random sample but will be selected to reflect a range of impact directions, vehicle types, manufacturers, and extent of burn damage.

In the second quarter of year 3, TRAC established most of the infrastructure required for completion of this project. The progress made, impediments encountered, and current status are summarized below.

- Investigations of three collision-fire events were performed in the quarter; two other investigations were scheduled for performance early in the next quarter.

- Procedures, forms and instructions have been refined with the information received in the first investigations.

- Continuing enhancements were made to the notification network so that knowledge of a range of events is received. The network is broad and agreements have been received from 21 cities and counties and state agencies. Contacts with police in several states are particularly well established. Texas, Ohio, and Illinois have repeatedly provided notices of events and assistance in investigations. Also, California has recently agreed to cooperate.

- Systems are in place that provide means of collecting data consistent with privacy regulations in the various jurisdictions and nationally. A Confidentiality Certificate has been issued by the U.S. Department of Health & Human Services "to protect the privacy of research subjects by withholding their identities from all persons not connected with the research." This certificate also engenders cooperation from law enforcement personnel.

- Investigations seek information about fuels involved in fire, likely ignition sources, fire propagation paths, fire propagation times, injuries, and Delta V.

The first five investigations involved the following events:

1995 BMW 525i	Frontal impact with barrier	Rupture of fuel rail with likely ignition from electrical arc.
1992 Mitsubishi Eclipse	Frontal impact with pickup	Release of engine oil and coolant directly on shielded, hot exhaust manifold.
1992 Ford Explorer	Side impact with car	Heater hose rupture, coolant release, likely ignition from electrical arc.
1996 Chrysler Sebring	Side impact with tractor-trailer	On-going
1991 Chrysler Acclaim	Frontal impact with pickup	On-going

Project B.3: Fire Initiation and Propagation Tests

Vehicle crash tests, including for example frontal and rear impacts, will be conducted. The crash test results, particularly the fluid plumes that result from component failures during the collision events, will be analyzed for fire initiation potential. These data will be used to develop a standard initiation protocol. Crash tested vehicles will be burned, using this standard initiation protocol; and fire propagation characteristics, such as component temperatures, flame spread and combustion off-gases, will be studied, particularly in their effects in the passenger compartment.

This project is being conducted by General Motors Research and Development Center (GMR&D) in collaboration with the Building and Fire Research Laboratory (BFRL) of the National Institute of Standards and Technology (NIST) and the Fire and Explosion Laboratory of Factory Mutual Research Corporation (FMRC). The principal investigators are Jack L. Jensen and Dr. Jeffrey Santrock of GMR&D; Dr. Thomas J. Ohlemiller of NIST; and Dr. Archie Tewarson of FMRC.

During the second quarter of year 3, a technical report entitled, "Evaluation of Motor Vehicle Fire Initiation and Propagation, Part 1: Vehicle Crash and Fire Propagation Test Program," was submitted to NHTSA.

The project consists of the following major tasks: (1) design and conduct vehicle crash tests to evaluate the performance of vehicle fluid and electrical systems, (2) design and conduct whole vehicle fire spread tests (using the vehicles crash-tested in Task 1), and (3) develop realistic fire initiation protocols for both under-hood and rear-end fuel-fed fires.

The oblique moving barrier impact on the Ford Explorer was completed at the GM Milford Proving Ground on July 30, 1997. A 1638 kg moving barrier (vehicle impactor similar but heavier than used for FMVSS214) impacted the Explorer at 105 km/h at the front left corner at 23 degrees from longitudinal. One-hundred fifty-two channels of information were recorded, again consistent with previously reported methodologies. Similar to previous tests, special instrumentation was included to identify possible ignition sources. The engine was running, and two fully instrumented 50^{th} percentile male Hybrid III crash dummies were used. Three different fire detection technologies were again evaluated for their crashworthiness. Data analysis is ongoing to determine potential post-collision fire ignition sources and will be documented in subsequent technical reports.

In addition to conducting the Explorer oblique-moving-barrier impact, the post-test inspections and disassembly were completed on the two crash tests conducted during the first quarter of year 3: (1) the 1997 Camaro 55 km/h offset pole impact, and (2) the 1997 Camaro 105 km/h oblique moving barrier impact. As outlined in the above technical report, the crash tested vehicles are disassembled to identify possible fire paths into the passenger compartment and to help identify any possible fire ignition sources.

A total of seven crash tests have been completed for project B.3. All of the crash testing has been completed on the Dodge Caravans and the Chevrolet Camaros. Two additional crash tests on the 1997 Ford Explorer are planned in the third quarter of year three and three crash tests are planned on the 1998 Honda Accord in the first quarter of year 4.

Two 1997 Chevrolet Camaros were instrumented for fire propagation tests and shipped to the Factory Mutual Test Center in Chepachet, Rhode Island.

The first test was conducted on September 30, 1997. The goal of this test was to characterize propagation of a gasoline pool fire located under the rear of the vehicle. The test vehicle was a production 97 Chevrolet Camaro with a 3.8L-V6 engine and automatic transmission. This vehicle was crash tested on January 8, 1997. The test vehicle was stationary and impacted in its left rear by a moving barrier, with a 70% overlap on the filler neck side of the vehicle. The barrier had a standard FMVSS 214 deformable face, with the bumper centerline positioned 432 mm (17 in) above grade. The vehicle mass was 1813 kg. The barrier mass was 1371 kg. The barrier speed at impact was 84.7 kmh.

The window in the left door, the hatch lid and rear window were broken during the crash test. The weld-seam in the left rear of the passenger compartment separated during the crash test. The fuel system of this vehicle did not leak during the crash test or subsequent static roll test.

One-hundred-eight (108) type-N thermocouples were installed in the vehicle to measure component temperatures and to track flame spread. Four heat flux transducers were installed in the vehicle to measure heat transfer to selected components. Six pressure taps were installed in the vehicle to measure air pressure gradients during the fire test. Assemblies containing three heat flux transducers and three radiometers were installed at approximately head-height over the driver and front passenger seats to measure convective and radiative heat transfer to front occupant positions. Aspirated thermocouple assemblies were installed above the front seats to measure air temperature in the passenger compartment. Sample ports were installed in the roof for chemical analysis of gases and particulates accumulating in the passenger compartment during the fire.

For the fire test, a leak in the fuel system was simulated by delivering gasoline continuously from a pressurized external receiver through a 0.25" o.d. copper tube. The outlet of the tube was fitted with a 0.125" flow restrictor and was located on the lower left edge of the fuel tank, directly under the point where the filler neck entered the fuel tank. The delivery rate of gasoline during the test was 500 mL/min. A pilot flame was used to ignite the gasoline pool 3 1 seconds after starting gasoline flow. The pool was fed with gasoline continuously during the test at 500 mL/min. The test was ended when flames propagated across the entire headliner, which occurred 3:19 (min:sec) after the gasoline pool was ignited.

During the fire test, the heat release rate of the fire was measured using the fire products collector at the Factory Mutual Test center. Data from the transducers installed in the vehicle was acquired at a rate of 1 Hz during the fire test. Air from the passenger compartment was sampled for chemical analysis of the gases and particulate produced by the fire. A detailed record of flame propagation was recorded by five video cameras located outside the vehicle, and four CCD cameras located inside the vehicle. A detailed record of the infrared radiation emitted by the burning vehicle was recorded by six thermal imaging radiometers located outside and inside the vehicle.

Project B.4: Evaluation of Potential Fire Intervention Materials and Technologies

> *Vehicle and component tests will be conducted of alternative materials and technologies that couldpotentially intervene in the initiation or propagation of vehicle fires.*

This project is being conducted by General Motors Research and Development Center (GMR&D) in collaboration with the Building and Fire Research Laboratory of the National Institute of Standards and Technology (NIST), under the terms of a Cooperative Research and

Development Agreement (CRADA) between GM and NIST. The principal investigators are Dr. Ismat Abu-Isa of GMR&D, Dr. Anthony Hamins of the Building and Fire Research Laboratory (NIST), and J. Michael Bennett of Dayton, Ohio.

For years 3-5, this project consists of the following major tasks (Note: Task 1 was developed in years 1-2):

Task 1.: Survey of Potential Fire Intervention Technologies.

During the second quarter of year 3, a draft report was initiated summarizing the results of the survey of fire intervention technology manufacturers and supplies conducted during year 2. These results will be used to help select promising fire intervention materials and technologies for intermediate-scale performance testing. Completion of the draft report is expected during the third quarter of year 3.

Task 2: Fire Test Scenario Development.

A fixture simulating a rear-end vehicle underbody was fabricated to test promising active suppression technologies. The device is a nearly full-scale mock-up of the rear of a typical small sedan. A rear-end gasoline pool fire scenario will be simulated by igniting a pool of gasoline leaked onto a cement slab. The gasoline leak location may vary, but will be near the filler neck or a seam in the fuel tank. After ignition of the simulated pool fire, an extinguishing agent will be deployed. The location of the agent delivery distribution system will be varied.

Task 3: Intermediate-Scale Testing of Materials and Technologies.

Suppression tests were conducted on rear-end fires using a fixture simulating a vehicle underbody. The underbody is a nearly full-scale mock-up of the rear of a small sedan. Gasoline was leaked (~1 L/min) onto a cement slab, ignited, and agent deployed within 2 to 10 sec. The leak location was varied including locations near the filler neck or the rear edge of the tank. The location of the agent delivery distribution system was positioned approximately 1 m forward of the fuel tank in the center of the underbody, consistent with survivability in a rear-end crash. Tests were performed using nitrogen pressurized mono-ammonium phosphate (ABC) powder. Several nozzle types were tested and nitrogen pressurization was varied.

Suppression tests were also performed in both the engine compartment and the rear-end fire simulators using a gas generator provided by Dynamit Nobel, a German company. Full-scale tests using actual vehicles are planned for next quarter.

Project B.5: Development of Crash Test Protocols

Crash test protocols (including barrier configuration, impact locations, and test speeds) that couldpotentially be used to enhance FMVSS 301 will be developed, based on analysis of collision data, case studies, vehicle testing and other relevant factors.

Paul T. Eichbrecht of GM Safety Center is the principal investigator for this project.

This project was refined, the statement of work was developed and agreed to by NHTSA, and initial project planning and development commenced during the second quarter of year 3. The project objective is to assess feasibility of crash test protocols that could potentially be used to enhance FMVSS 301, "Fuel System Integrity." GM will conduct five (5) rear-impact tests utilizing a test condition developed in related NHTSA research tests. The test condition is an 80 km/hr, 70% offset, colinear rear impact using the FMVSS 214 deformable moving barrier. The barrier face height relative to ground will be lowered 51 mm from its FMVSS 214 position to simulate impacting vehicle brake dive. The tests will be conducted on the following five (5) small 1998 4-door cars: (1) Chevrolet Cavalier, (2) Ford Escort, (3) Honda Civic, (4) Nissan Sentra, and (5) Volkswagen Jetta. These cars were chosen based on the following criteria: (1) market segment sales leaders with 100,000 or more units sold, (2) curb weight under 3000 pounds, (3) no more than one vehicle in the selected group from a single manufacturer, and (4) the car (or its "sister" version) was not previously tested by NHTSA in its related research. Testing is anticipated to begin in the third or fourth quarter of year 3 and to be completed by the end of year 3.

Project B. 6: Analyses of Failure Modes and Effects for Alternatively Fueled Vehicles

Failure modes and effects analyses (FMEAs) will be prepared and unique potential fire hazards associated with generic designs of alternatively fueled vehicles will be analyzed. Priority of analyses shall be given in the following order: CNG fueled vehicles, propane fueled vehicles, electric vehicles and hybrid vehicles.

Failure Analysis Associates (FaAA) is the contractor for this project. John Moalli, Sc.D., is the principal investigator for this project.

A draft final report summarizing the results of a comprehensive analysis of natural gas-fueled vehicle fuel system failure modes was completed during the fourth quarter of year 2 and submitted to NHTSA. During the second quarter of year 3, this draft report was undergoing review by external peer reviewers selected by NHTSA.

Project B. 7: *Development of Criteria and Methodologies for In-Service Inspections of Gaseous Fuel Pressure Vessels*

A proposed in-service inspection schedule, inspection protocol, and acceptance criteria will be developedfor gaseous fuel pressure vessels used in motor vehicle applications.

Failure Analysis Associates (FaAA) is the contractor for this project. John Moalli, Sc.D., is the principal investigator for this project.

During the fourth quarter of year 2, an acoustic emission testing program was initiated. During the second quarter of year 3, a draft technical report was prepared and submitted to NHTSA. During the second quarter of year 3, this draft report was undergoing review by external peer reviewers selected by NHTSA.

Project B.8: *Search of Scientific Literature*

Scientific literature will be searched to locate papers concerning: flammability of interior and exterior materials used in motor vehicles or in passenger carriers for other modes of transportation; the chemistry offlame retardants and their combustion products; and the toxicological effects of off-gases produced by the combustion of such materials. The search will also include related material in respect to alternativelyfueled vehicles. The search will build upon efforts currently being undertaken by other organizations. A database will be establishedproviding citations, abstracts, and associated key words,

Douglas E. LaDue III, of General Motors Research and Development Center, is the principal investigator for this project.

During the second quarter of year 3, the computerized database was reviewed and checked for inconsistencies or bugs. A draft summary report summarizing this database was prepared, in preparation for the submission of the database, user's manual and final summary report to NHTSA during the third quarter of year 3.

Project B.9: *Inspection of Aging Vehicles and Testing of Components*

Aging vehicles will be inspected to collect data concerning the state of repair and level of deterioration in physical properties offuel system components, including the frequency and effects of tampering and improper service. Sample materials will be obtainedfor lab testing and characterization.

Southwest Research Institute (SWRI) of San Antonio, Texas, in collaboration with McLaren Engines, is the contractor for this project. The principal investigators for this project are Michael Miller (SWRI) and Thomas Hanson (McLaren Engines).

During the second quarter of year 3, the following work was performed:

- Six additional vehicles were procured. Components were removed and shipped to SWRI for analysis.
- The allowed vehicle mix was revised from 10-12 years old to 8-12 years old. This was done so that a wider variety of fuel system material technologies can be examined.
- Characterization of component condition was begun. Plans are underway to begin detailed surface analysis of a variety of materials.
- Documentation of the results is ongoing.

Plans were made for a site visit by NHTSA and GM personnel to Southwest Research in November of 1997 to evaluate component testing facilities and methodologies.

Project B. 10: Study of Flammability of Materials

> *Engine compartment fluids (other than gasoline) and vehicle interior and exterior materials will be studied, using existing laboratory test methods as appropriate, as to their flammability properties and limits. For selected materials, efforts will be made to identify or devise cost effective, less flammable substitutes which would not compromise other important physical properties.*

This project is being conducted by General Motors Research and Development Center (GMR&D) in collaboration with the Building and Fire Research Laboratory (BFRL) of the National Institute of Standards and Technology (NIST) and the Fire and Explosion Laboratory of Factory Mutual Research Corporation (FMRC). The principal investigators are Ismat Abu-Isa of GMR&D; Dr. Thomas Ohlemiller of NIST; and Dr. Archie Tewarson of FMRC.

Work to characterize the flammability properties of automotive materials is being conducted by each of these three organizations and is detailed in the Annual Report for year 2.

During the second quarter of year 3, a technical report entitled, "Thermal Properties of Automotive Polymers - I. Thermal Gravimetric Analysis and Differential Scanning Calorimetry of Selected Parts From a Dodge Caravan" was submitted to NHTSA.

GMR&D Activities

Study of the thermal properties of polymeric parts taken from a 1997 Dodge Caravan is now completed. During the second quarter of year 3, we determined the conductivity at 100 °C of some of the parts using a procedure developed for Modulated Differential Scanning Calorimetry. The procedure allows a fast measurement of thermal conductivity as compared to traditional methods. We moved on to the study of thermal properties of polymeric parts taken from a 1997 Camaro. As many polymeric parts as possible will be chosen to yield information that will complement, rather than repeat, information obtained from the Dodge Caravan investigation. Parts for the study were identified and ordered. Polymer identification for these parts were started. It was decided that one set of the parts will be sent to each of NIST and Factory Mutual.

Planning for the study of alternative fire retardant materials was started. It was decided that two commodity automotive polymers will be identified for the study and that the effectiveness of state of the art fire retardant technologies on flammability, mechanical and thermal properties of polymers will be assessed. Plans were made to make slabs, sheets and generic shaped automotive parts of the commodity polymers and their fire retardant compositions at our laboratory for the study.

Several flammability experiments were conducted using a Federal Aviation Administration Flammability Chamber. Samples of a commercial polypropylene resin were molded and burnt in the chamber in vertical, horizontal and 45 degree orientations. A more intense flame was used for ignition than the flame specified in FMVSS 302. In addition to flame spread, weight loss data due to dripping and burning were collected. As expected, samples performed best in the horizontal orientation. In the vertical and forty five-degree orientations the flame spread rates were similar but the weight consumed in fire and the weight loss due to dripping were larger for the vertical sample. Based on this data a sample holder and a load cell were configured in order to obtain weight loss data with time during burning. The new apparatus will give better quantitative results and more flammability data than what is obtainable now with the FMVSS 302 test.

The effects of crosslinking and stabilizers on flammability of polyolefin elastomers were investigated using the FAA chamber. Even a light degree of crosslinking appreciably reduced the rate of flame spread, and the degree of dripping in these elastomers. Heat stabilizers had little influence on flammability when used alone, but were effective when the elastomer was crosslinked.

Factory Mutual Research Corporation Support Activity

The plastic parts from the Camaro selected for testing were received, so they could be catalogued and tested. The High Energy Calorimeter was redesigned by the manufacturer. Several plastic manufacturers were contacted regarding the improved PP and PE, (i.e., reduced melting characteristics, high CHF and TRP values, and low HRP, PRP, and FPI values). The improved polymers were available for research.

A Differential Thermal Analysis (DTA) apparatus, using large samples (5 to 10 gms) was used in France for many years for coal research. This apparatus appears to be useful for the B.10 project, as the use of larger samples eliminates problems with non-homogenous polymers. Effluent gas analysis can also be performed.

Plans were made to contact the French scientists to obtain further information. We modified our fire propagation test slightly as we want to monitor melting behavior along with the fire propagation behavior to complement the NIST research on this subject. We are continuing to develop correlations between the thermal properties measured by GM and the flammability properties measured by FMRC for the plastic parts and their relationships with the large-scale vehicle burn test results.

NIST Support Activity

Task 2. Characterize Liquid and Solid Combustibles

A draft report describing the fire test results on selected components from a minivan was prepared for internal review.

Task 3. Identify Potential Alternative Materials

A simplified, generic underhood component was designed as a testbed for polymeric materials containing flame retardants. GM will make the parts using vacuum molding. Efforts are now underway to identify candidate commercial polymer resins that will be incorporated into the part and subjected to the same type of fire testing as was used in Task 2 above. Non-flame retarded versions of essentially the same resins will be tested as reference cases.

Project B. 11: Study of Component Influence on Vehicle Fires

> *The effect of specific components on the frequency of fuel leakage in collisions and the likelihood of ignition will be studied. Laboratory tests will be developed to evaluate component performance.*

SEA, Incorporated of Columbus, Ohio, is the contractor for this project. Gary Heydinger, P.E., is the principal investigator for this project.

During the second quarter of year 3, SEA designed an impactor device for rupturing the Onboard Refueling Vapor Recovery (ORVR) canisters. The device is a gravity driven pendulum. The pendulum energy and momentum were chosen based on the results of initial experiments on canister rupture. The contractor also attempted to approximate the impact speed of a collision that would cause damage but probably would not kill the occupants of a vehicle. The Parts for the impactor have been machined and assembly is anticipated during the next quarter.

The piping for the canister loading unit is complete and the temperature control is nearing completion. A fuel delivery protocol was developed and will be refined based on probe tests of the technique. Canister loading should be ready by the time the initial, unloaded canister rupture tests are complete.

Three general classes of sources of fire ignition have been initially identified: (1) sparks, (2) hot surfaces, and (3) flames. Representatives of each class will be tested for their ability to ignite ejected carbon particles from a loaded canister. Flame sources are currently planned for the formal ignition tests of the ruptured canister, though high-voltage electrical sparks have not been ruled out.

A site visit is tentatively planned for the 19th of November prior to the first unloaded rupture tests. The site visit is intended to ensure the tests being planned and the methods being used conform with GM's expectations for the program.

Project B.12: This project was canceled per agreement between NHTSA and GM.

Project B.13: Development of Technical Information for Dissemination to First Responders

The purpose of this project is to identify information obtainedfrom tasks in these fire relatedprojects that would be useful to first responders (police, fire, and emergency medical services).

This project depends upon results obtained from Projects B.1 through B.11. It is anticipated that relevant technical information developed in these research projects will be made available to first responders as soon as practicable. The mechanisms for determining what information should be conveyed to first responders and how this information should be conveyed have yet to be determined by GM and NHTSA technical staffs. During the second quarter of year 3, GM and NHTSA staffs continued to discuss possible ways in which technical information developed in the fire safety research projects could be disseminated to first responders and other individuals and organizations concerned with vehicle safety issues. Plans were made to develop a statement of work for this project during the next six months.

Project B. 14: Demonstration of Enhanced Fire Safety Technology

The purpose of this project is to demonstrate vehicle or component characteristics or materials that have been identifiedfrom tasks in thesejire relatedprojects that can lead to enhancedfire safety technology.

This project depends upon results obtained from Projects B.1 through B.11. In particular, information from Projects B.3, B.4 and B.10 is required before this project can be initiated. No work was conducted on this project during years 2 or 3 Plans were made to develop a statement of work during the fourth quarter of year 3.

Project B.15: Theoretical and Experimental Study of Thermal Barriers Separating Automobile Engine and Passenger Compartments

Thisproject will examine various fire insulationsfor their role in the prevention offire spreadfrom an automobile engine compartment to the passenger compartment through the bulkhead. The thermal response of the various combinations of materials will be characterized. The project will involve experimental, theoretical and numerical parts.

Professors Indrek S. Wichman and James V. Beck of Michigan State University are the principal investigators for this project.

During the second year, GM and NHTSA agreed to add an additional project to the fire safety research program. A statement of work for this study was submitted and approved during the fourth quarter of year 2. This one-year study, to be conducted by Professors Indrek Wichman and James Breck from the Department of Mechanical Engineering at Michigan State University, is for the examination of the effectiveness of the forward bulkhead in preventing fire transmission to the passenger compartment. This research will be used to describe heat transfer through intact bulkheads (i.e., bulkheads whose structural integrity has not been compromised by a crash) and will attempt to identify: (1) material properties that can effectively reduce the transient heat flux across the layered material constituting the thermal barrier, and (2) materials that could substantially alter the rate of heat transfer across the thermal barrier. This project was initiated during the first quarter of year 3 and is expected to be completed by the end of year 3.

Efforts in the second quarter of year 3 were experimental and computational. Tests were carried out to determine the thermal properties of the barrier materials. The properties dictate the heat flux through the material. The computations utilized thermal models to investigate the response of layered materials to the heat fluxes imposed on one side. Direct and inverse heat conduction codes were jointly used to determine which layers are most important for reduced heat flux transmission.

The experimental tests show that the previous arrangement, described in the proposal, cannot accurately measure the thermal properties of the GM supplied materials. One feature of a well-designed property-measurement experiment is that the values of the sequential parameter estimates, plotted versus time, should approach constant values in the final part of the test, following initial fluctuations. Results for the glass fiber, rubber, and the Cadillac headliner fail to show such a trend. Nevertheless, the property values obtained are within the ranges found in the literature. The tests established the glass fiber conductivity as 0.044W/mK, which lies within the literature range 0.018 to 0.058 W/mK. These results are not sufficiently accurate, however. Because the high accuracy determination of properties is crucial to the project, the original experiment is being modified to enlarge the sensitivity of the measured variables. This will enable more accurate property measurements.

Because of the above experimental difficulties, literature values of the thermal properties in the computations were used. The literature values vary widely; hence it is difficult to determine their precise influence on the numerical results. A procedure was established for: (1) finding the heat flux on the unheated side of the thermal barrier, and (2) making parametric studies of the barrier effectiveness based on individual layer thicknesses and their properties. Preliminary results show that the most important layers are those such as the glass fiber layer. The supportive layers, such as the facing cloth or the rubber, contribute weakly to the reduction in heat transmission. Plans were made to use actual experimental data from GM in the simulation.

I.D. Crash Test Dummy Research & Development

The project descriptions stated in this report are the ones that were in effect on September 30, 1997, the last day of the quarter covered by this report. Since then, some of these project descriptions have been revised. In future progress reports, the revised project descriptions will be used, providing they are in effect on the last day of the period covered by the report.

Project D. 1: Development of High-Speed Chest Deflection Sensor for All Dummy Family

> *The research effort in the first two years will be continued. Extensive in-dummy testing of the IR-TRACC system (Infrared Telescoping Rod for the Assessment of Chest Compression) developed in years I and 2 will be performed under a variety of conditions to assure that the system is robust. Implementation in all of the various sized members of the Hybrid III family will begin. Since the telescoping rod length will need to be adjusted to range from 3-year old child to large male, it is anticipated that some additional development will be necessary.*

Stephen W. Rouhana, Ph.D., of GM Safety Research, is the principal investigator for this project.

The IR-TRACC system was tested in a telescoping rod designed for a 3-year old Hybrid III dummy. The telescoping rod was designed to measure the largest amount of displacement possible within the constraints of the thorax of the dummy. In order to accomplish this there were five segments in the telescoping rod with minimal overlap between one another. This allowed for the smallest possible overall length in the rod when it was compressed. On the other hand, the small overlap allowed for approximately 10% wiggle error.

In order to solve the wiggle problem, two steps were performed. The first step was to redesign the telescoping rod. The telescoping rod was replaced with the four largest segments of the telescoping rod from the TAD-50M (NHTSA's prototype advanced dummy). These four segments have over 6 mm of overlap between one another and the fully compressed length was increased by approximately 6 mm. The second step was to replace the IR light source and receiver. Instead of using a normal IR LED and phototransistor, a fiber optic LED and phototransistor were mounted to one end of a bifurcated fiber optic cable. The opposite end of the bifurcated cable has a 90° hypodermic tip. This end tip was mounted rigidly in the smallest segment of the telescoping rod. Retroreflective tape was attached to the inside (on the base) of the telescoping rod. The IR light is now transmitted through fiber optic fibers, reflected off the base of the rod, and received back through different fiber optic fibers. Both the transmitting and receiving fibers are bundled into the same single bifurcated cable. The fiber optic cable by itself reduced the wiggle error to approximately 4 to 5 percent. When tested along with the redesigned telescoping rod, the wiggle error dropped to less than 1%.

A Hybrid III 3-year old child dummy was not available but a 5-rib chest with leather sternum was used, which also had the anthropometry of a 3-year old. Since the sternum in the dummy chest is made out of leather it was quite flexible. Using the original IR-TRACC setup, the maximum displacement that could be measured was approximately 24 mm. The IR-TRACC data closely approximated the high-speed film data, although the IR-TRACC data showed a small negative spike at initial impact. Review of the high-speed film showed that the impactor did not initially hit the sternum flush, which caused the sternum to tilt before chest compression began. This tilting motion may have caused the negative spike. While it is difficult to be certain what caused the spike, it was likely caused by one of three possibilities: (1) the actual displacement of the chest, (2) the tilting of the sternum under impact, or (3) the error due to wiggle in the rod. This spike appears consistently over several different impacts.

Further testing was performed using a system that UMTRI developed to test the telescoping rod of the TAD-50M advanced dummy. This setup decreases the potential for uncertainty in determining the rod length. All tests performed using UMTRI's setup were conducted with an impactor velocity of 6 to 7 m/s before hitting a 6 by 6-inch plate and crushing a block of Hexcel thereby damping the impact to the telescoping rod. The rate of compression of the telescoping rod was approximately 1 m/s. Three displacement measuring instruments were tested on this setup: (1) the original IR-TRACC system with a five-segment telescoping rod, (2) the new fiber optic IR-TRACC system with a four-segment telescoping rod, and (3) an optical chest deflection sensor developed by First Technology Safety Systems with a five-segment telescoping rod, also using the same original five-segment telescoping rod. In all cases, the measured displacement was compared to displacement obtained from high-speed film analysis and a linear potentiometer. Both systems using the five-segment telescoping rod exhibited many spikes in the data. The fiber optic IR-TRACC system data closely overlapped the high-speed film and linear potentiometer data (± 1 mm variance). The fiber optic IR-TRACC system data did not exhibit any spikes.

The fiber optic IR-TRACC system mounted in the four-segment telescoping rod is linear for a minimum of 30 mm. The fiber optic IR-TRACC system mounted in the advanced telescoping rod is linear for a minimum of 50 mm. The fiber optic IR-TRACC in a 8.5-inch telescoping rod generates nonlinear data. The beam angle of the IR light transmitted from the bifurcated cable covers a larger area than the base of the rod. The beam angle is correlated to the numerical aperture of the fiber optic cable. A fiber optic cable with numerical aperture of 0.25 instead of the present 0.55 is being custom built.

A 0.72-inch length Y-shaped fiber optic cable with numerical aperture of 0.55 has been custom built to fit inside the smallest segment of the four-segment telescoping rod. This eliminates the large 3-foot long fiber optic cable that has been used. A 0.25 numerical aperture Y-shaped fiber optic cable is also being built. The Y-shaped fiber optic cable has not been tested using the UMTRI setup.

Further testing will be performed using a Y-shaped fiber optic cable of 0.25 numerical aperture. Also further testing is planned for the fiber optic IR-TRACC system with the rebuilt four-segment dummy rod and the 8.5-inch telescoping rods at speeds up to 18 m/s.

Project D. 2: Development of Reusable, Rate-Sensitive Abdomen

The research effort in the first two years will be continued. Tests using human cadavers to complete the biomechanical corridors will be completed. Prototype abdominal inserts will begin in-dummy testing to evaluate tethering and the effect of the abdomen on other Hybrid III responses (e.g., thoracic response). Instrumentation to measure appropriate physical correlates will be developed and integrated into the abdominal inserts.

Sub-Project D.2 (a): Development/Refinement of Abdominal Response Corridors and Tissue Properties

Lawrence W. Schneider, Ph.D., of the University of Michigan Transportation Research Institute, is the principal investigator for this sub-project.

During the second quarter of year three, activities focused on modification and use of the test apparatus for abdomen whole-body impact-response testing, based on the knowledge gained in the tests conducted during the first quarter of year 3. In particular, attention was directed to cadaver perfusion and positioning techniques. Fabrication and assembly of the previously designed tissue testing device have been nearly completed.

Test procedures include dressing the cadaver in leotards and tights. The cadaver is positioned in a seated, upright, free-back posture, with the legs positioned forward. The hands are suspended in front of and above the head to eliminate their involvement in the impact. The cadaver is seated on a curved plastic skid that can be adjusted using spacers. The abdomen is impacted at the level of the umbilicus at a speed of approximately 6.7 m/s, using a 48 kg ballistic pendulum with a 2.5 cm diameter rigid-bar impact face.

A safety harness is buckled around the cadaver, under its arms, in order to hold the cadaver in position prior to impact. D rings on the harness are positioned above each shoulder and attached to adjustable tiedown assemblies via S hooks. The opposite ends of the tie-down assemblies are attached to a central ring via S hooks. Over-center buckles allow the posture of the cadaver to be easily adjusted. The central ring is suspended by a swivel snap shackle that is actuated (i.e., opened) by a remote solenoid through a flexible cable. This shackle is attached to the top and center of the main pendulum and cadaver support structure, but does interfere with the overhead camera view. The shackle can be moved forward, backward, and from side to side, depending on the test conditions and specimen anthropometry. The harness also has a posterior ring to which the belt of a retractable lanyard is latched. The retractor mechanism is fastened to a rigid beam above the test platform. A cargo net is suspended from this beam using elastic straps, and the bottom of the net is attached to the test platform using pear-shaped threaded chain connectors. This rigging was designed to catch the cadaver after impact.

Anteroposterior and inferosuperior acceleration measurements are made at four locations using mounts fixed to T1, L3, S1 and the body of the sternum via tapered Steinmann pins. Impact load, moment in the median plane, and acceleration are also measured. Dual-marker target masts are attached to the locations of all accelerometers to facilitate kinematic analysis using high-speed film. Overhead and lateral perspectives are filmed at 1000 fps. Solid-state timers visible in each camera field are triggered by a contact sensor on the anterior surface of the abdomen to provide a synchronizing signal for data acquisition.

Millar pressure catheters are positioned in the stomach, sigmoid colon, abdominal aorta, and urinary bladder. The Millar units are installed through 30 cc Foley catheters, so that the esophagus, rectum, femoral artery and urethra can be sealed and/or perfused. The bladder is first evacuated, and then receives 250 cc of normal saline. Pretest x-rays are used to verify the instrumentation locations.

Particular attention was given to develop the perfusion technique prior to the first test. Prior to the perfusion with normal saline mixed with methylene-blue stain, the vascular system of the cadaver is flushed with approximately 30 liters of normal saline and the cadaver is allowed to reach room temperature. Warm saline is then pumped into the right common carotid artery using approximately 28 kPa, and the blood and clots are allowed to exit from the right internal jugular vein. Clot removal is assisted by repeatedly inserting long angled forceps into the superior vena cava. Even the superficial vasculature is flushed during this procedure. Raising, lowering, and massaging of the limbs aids the process. Care is taken to limit the pressure and amount of fluid so as to avoid accumulation of considerable interstitial abdominal fluids. Foley catheters and compression fittings are used to fabricate bilateral descending perfusion attachments to the carotid arteries and jugular veins. Access to the abdominal aorta is obtained through the right femoral artery. Similarly, access to the inferior vena cava is gained through the right femoral vein. The external iliac artery and vein are perfused on the left side through the left femoral artery and vein. Good perfusion of the mesentery is evident under x-ray and at autopsy. For future testing, consideration is being given to using antibiotics in the perfusing fluids to slow the rate of tissue decay that can be accelerated by a heated perfusion process. Clot destroying (as opposed to preventing) agents such as PlasmaFlow are also being investigated.

Prior to impact, the cadaver is given a few "full breaths" through a tracheostomy tube. The perfusion device is activated, pumping 13.8 kPa heated normal saline mixed with methylene-blue stain into the arterial system. Fluid returns to the perfusion device through the venous system. The lights are brought up, the cameras were started, and the cannon is fired. The ballistic pendulum releases from the electromagnet as the pneumatic cannon is fired, and computer sampling is triggered shortly afterward (prior to abdomen impact). The pendulum passes through the beams of an infrared speed trap mounted between the cadaver's knees. Approximately 10 ms prior to the pendulum contacting the abdomen of the cadaver, the shackle supporting the cadaver harness is released. Upon impact, the cadaver is propelled into the cargo net, and the retractable lanyard ensures that the cadaver remains in the net. The harness and its associated rigging does not interfere with the test, and the cadaver does not slump prior to the impact.

One test was conducted using the above protocol. An autopsy was conducted within a few days of testing and showed that the spleen, stomach, kidneys and mesentery were uninjured. Bilateral fractures of ribs 7, 8 and 9 were found and may have resulted from the rigid-bar impact, but bilateral fractures of the sixth ribs were due to CPR that the subject received prior to death. Other injuries noted include a 9-cm transverse tear of the left side of the diaphragm, a 10-cm tear of the cecum, a 7.5-cm tear of the anterior portion of the right lobe of the liver, and a 9-cm tear along the posterior surface of the liver. Instrumentation data are being processed and analyzed to produce the force-deflection response for comparison with previous findings.

An oral presentation entitled, "Methods for the Investigation of Impact-Induced Abdominal Injuries," is scheduled for the 25th International Workshop on Human Subjects for Biomechanical Research, to discuss the abdominal impact data obtained by previous researchers and the experimental design of this project. Participation in a panel discussion concerning perfusion is also anticipated.

Most of the components for the previously designed tissue testing apparatus have been fabricated or obtained. The pneumatic actuator, valving and clamping mechanisms have been mounted to the test fixture. Tissue testing is expected to begin during the third quarter of year three, and whole-body abdominal impact testing is scheduled at the rate of approximately one specimen per month.

Sub-Project D.2 (b): Development of Abdominal Hardware and Instrumentation

Stephen W. Rouhana, Ph.D., of GM Safety Research, is the principal investigator for this sub-project.

The manufacturer of the sheet constructed bladders (Linden Industries, Ohio) was not able to make a leak-free, three-dimensional bladder. Hence this method of developing the bladder was not further pursued. More effort has been directed towards producing a molded bladder.

A modified solid model with tethering flanges and registers was created using the laminate object manufacturing process. Using this model, First Technology Safety Systems (FTSS) built a fiberglass mold. The mold was used to make a hard foam copy of the solid model which will be easier to modify as development continues. Hard foam copies can also be sent to other manufacturers that might be able to mold bladders with different materials or processes than FTSS.

FTSS has been attempting to mold the required bladder using several methods. One method is similar to slush molding. In slush molding, the mold is preheated and filled with plastisol (vinyl) until it gels and the excess is drained. The mold is then cooled and the part is pulled out of the mold. Since polyurethane is a cold cured product and it requires a longer time to cure, FTSS judged this process as inappropriate especially for a controlled thickness bladder.

In order to better control the thickness of the bladder, FTSS created a mold that fits inside the female mold with a gap between the two molds equivalent to the desired thickness of the bladder. In this method, four spacing pins were needed to keep the inside mold at a controlled distance away from the female mold. Therefore, the molded part had four holes in it. In order to remove the inside mold, a slit approximately 10-inches long was made on the top of the part. The holes and the slit were sealed with glue. This process produced what seemed to be a strong bladder but, was not airtight. To overcome these problems, two changes were suggested. The inside mold can be made out of wax so that it can be melted and poured out of the spacer holes in the part thus eliminating the need for a slit. The second suggested change is to make the spacer holes with quarter-inch extensions outside the bladder. The bladder would then have four hose-like *structures* instead of four holes. These structures could then be mechanically sealed, thereby eliminating the need for gluing.

Another manufacturer, Mannetron Animatronics in Battle Creek, Michigan, is also trying to identify a method to produce an abdominal bladder based on a molded silicon shell and gel filling. A sample bladder is being shipped for evaluation. Other companies are also being contacted to search for an appropriate manufacturing process. In addition, more elastomeric samples are being evaluated using the hydraulic testing machine (MTS) to identify more candidate materials for the shell of the bladder.

The immersible ultrasonic transducers were tested on the MTS employing the principle of the Doppler effect to measure velocity. An emitter was attached on the top of a water filled bladder and a receiver at its bottom. As the emitter was pushed towards the receiver and away from it, the frequency of the received signal was monitored. Analysis of the signal showed that the signal contained noise that was probably produced by the reflection of the signal from the walls of the bladder. Alignment of the transducers also appeared to be critical. For these reasons, research in that area has been halted.

Discussions about instrumentation using the Micropower Impulse Radar (MIR) continued. A team from Hughes Research Laboratories visited to get better acquainted with the project. Special problems relating to metal interference, reflectivity, and multipath problems have been discussed.

Project 0.3: Refinement of Crash Test Dummy Necks

The research effort in the first two years will be continued. A review and analysis of existing data on neck biomechanical response will be performed and will be combined with simple modifications of the existing Hybrid III neck design to allow the Hybrid III dummy to produce more realistic head trajectories, attitudes, and contact interactions in restraint system tests and reliable interactions with inflating airbags, while retaining its present bending (moment-angle) behavior. The analysis phase will concentrate on defining requirements for head trajectory and response behaviors for well-defined test conditions. The analysis will be *based on the responses and trajectories from human volunteer forward flexion tests, cadaver rearward extension tests, and air bag neck loading responses in out-of-position cadaver tests. The experimental work will involve design and fabrication of neck modifications and testing to demonshate compliance with the requirements defined by the analysis. Sled testing of the whole dummy with the modified neck under specific conditions related to head trajectory definition and air bag interactions will also be performed.*

Sub-Project D.3 (a): Film Analysis of Head Kinematics

Paul C. Begeman, Ph.D., and Albert I. King, Ph.D., of Wayne State University, are the principal investigators for this sub-project.

During the second quarter of year 3, six tests previously conducted at Wright-Patterson Air Force Base (WPAFB) were digitized using photogrammetric methods. The trajectories of the head center of gravity, relative to the torso reference, were found differently for different restraint systems. After reviewing the loading phase results of 24 tests from three different databases, a new analysis approach to obtain the reference for the head CG trajectory and the neck response was proposed. The uniform reference is necessary to obtain the head responses in a consistent way and to minimize the effects of the different test setups used for the different tests. A C++ program was written to carry out the detailed calculations. Two tests were analyzed using the new method.

Sub-Project D.3 (b): Biomechanics of the Human Cadaver Neck Due to +Gx Torso Acceleration

Paul C. Begeman, Ph.D., and Albert I. King, Ph.D., of Wayne State University, are the principal investigators for this sub-project.

During the second quarter of year 3, one human cadaver was tested using the specially designed HYGE-type mini-sled and a high-speed, bi-planar x-ray system. The three-dimensional cervical vertebral motions during simulated rear-end automotive collisions were recorded and analyzed using x-ray images as well as photogrammetry. Two different seatback angles (0° and 20°) were tested using a single specimen.

The relative kinematics of each cervical vertebrae can be determined from implanted targets in the vertebral body. Chrome steel balls, 2-mm in diameter, were fixed to each vertebra in the following locations: (a) in the posterior spinous process, (b) in the right or left transverse processes, and (c) in the anterior aspect of the vertebral body. To minimize surgical disruption to the neck structures, steinmann pins were used to locate the placement, with X-rays used to guide each step of the placement. Through a guide, 2-mm diameter holes were drilled to a depth of 2-mm into the bone. The steel balls were inserted into the holes percutaneously via a tube and a probe. After placement of the steel balls into the holes, the holes were sealed with beeswax. CT scan of the neck was taken on the specimen to determine the geometry of the cervical spine.

The high-speed bi-planar X-ray is a continuous, non-gated system. The unit has two sets of X-ray heads and intensifiers mounted to a dual overlapping gantry fixture. The two pairs are 60° apart in the horizontal plane. The X-ray vision range is 12 inches by 12 inches. Three-dimensional motions of the cervical spine were quantified from the instantaneous positions of the chrome balls. The critical event in the neck occurred within 200 ms of the onset of acceleration. X-ray images of vertebral motion were acquired at 250 frames per second.

The cadaver was positioned in a rigid aluminum seat using a lap belt and a strap across the upper torso and seatback. The head was held roughly vertical to obtain the neutral position of the neck. The specimen was instrumented with a triaxial accelerometer unit which was screwed to the T1 vertebral body. The 3-2-2-2 array was screwed to the top of the skull to obtain the head accelerations and thereby enable calculation of the neck loads at the occipital condyles. The sled acceleration was recorded in the +x direction. Photo targets were placed to the head, T1 and seatback. A floor-mounted high-speed camera running at 200 frames per second recorded the head-neck motion in the anterior-posterior plane. The films were digitized to obtain the head and T1 rotations. The acceleration data was processed according to recommended practice SAE J211. The data from the nine-accelerometer array were analyzed according to rigid body kinematics. The linear and angular accelerations at head CG, the shear and axial forces and the bending moments at the occipital condyle were calculated. The calculated head extension-flexion angles were compared with the film analysis results.

Different neck responses were found for two seatback angles. Initial neck compression was observed for both tests.

Autopsy was performed to document injury to the neck. A broken disk was found on the anterior left side of C7/T1 and an anterior disk separation was found between C5 and C6.

Sub-Project D.3 (c): Hybrid III Neck Improvements

John Melvin, Ph.D., of GM Safety Research, is the principal investigator for this sub-project.

The modified neck developed in this sub-project cannot be used as a simple replacement for the standard Hybrid III neck. Both the thoracic spine and the shoulder must be modified to accommodate the modified neck.

During the second quarter of year 3, arrangements were made by First Technology Safety Systems to purchase a modified Hybrid III thoracic spine structure and associated shoulder pieces to allow incorporation of a modified neck within a Hybrid III dummy. Sled test procedures for simulating the human volunteer tests were developed and baseline tests were performed with a standard Hybrid III dummy.

Sub-Project D.3 (d) Analysis of Air Bag Interactions with the Head and Neck

Paul C. Begeman, Ph.D., and Albert I. King, Ph.D., of Wayne State University, are the principal investigators for this sub-project.

Work was initiated on this sub-project during the second quarter of year 3. The various data sources are being organized and reviewed for the analysis phase of the sub-project.

Project D.4: Identification of Injury Mechanisms Resulting in Injuries to the Upper Extremities in Frontal Crashes

The advent of inflatable restraints has led to anecdotal reports of upper extremity injuries allegedly caused by the deploying air bags. This project will use accident and laboratory investigative techniques to quantify the extent of such injuries in the real world and to identify how these injuries occur. If the mechanisms of injury are quantified, efforts will be made to develop techniques that may mitigate the identified hazards.

Lawrence W. Schneider, Ph.D., of University of Michigan Transportation Research Institute, is the principal investigator for this project.

Activities during the second quarter of year 3 focused on the processing and analysis of the data obtained from the six previously conducted upper-extremity air bag-interaction static deployments, using two different air bag systems, considered more or less aggressive. In addition, a dynamic-deployment simulation fixture has been designed, MADYMO modeling has continued, and four new crash investigations of frontal impacts involving forearm fractures and steering-wheel air bag deployments into drivers have been initiated.

Newly developed forearm fracture predictors from a related project, including peak distal forearm speed (PDFS) and average distal forearm speed (ADFS), were calculated for this set of data to further examine the predictive ability of these parameters across differing air bag systems. The additional data from this project were then used to update and refine PDFS and ADFS fracture models. In conjunction with this analysis, an equal stress / equal velocity scaling was performed on the measured internal air bag pressures using upper extremity mass and a forearm form factor (FFF) which was based upon the geometry of the forearms. The difference in the fracture prediction capability of this technique within a set of similar air bags as opposed to across sets of dissimilar air bags was examined. In addition, the internal air bag pressure responses for the different air bag systems were examined with respect to time. The results show that while internal air bag pressure might be used to predict forearm fracture within a set of similar air bags, it is not a good predictor of forearm fracture across different air bag modules. However, internal air bag pressure may provide information relevant to the effectiveness of design countermeasures when comparing various air bag modules. A paper is being prepared on these data for presentation at the 1998 SAE Congress.

The laboratory facility for these tests has been set up to perform the two remaining deployments of "more" and "less" aggressive air bag modules as soon as a suitable specimen becomes available. A request has been made for an approximately 55 kg female cadaver with a stature near 160 cm. Upon completion of these deployments, testing will shift to dynamic and fling injury simulations. To that end, a fixture has been designed to simulate dynamic interaction of the air bag module and upper extremity using an actuated steering column. Inertial effects and the role of soft tissues are to be examined using this fixture. Also, the previously designed windshield, header, and roof assembly has been improved to provide greater range of adjustment and rigidity for investigation of fling injuries.

Refinement of the MADYMO model continued during this quarter, focusing on improvement of the air bag deployment simulation. Once the air bag and forearm kinematics of the model become representative of the empirical data, the model will be exercised to study proximity and inertia effects on distal forearm speed and internal bending moments.

Four new cases involving steering-wheel air bag deployments and forearm fractures to drivers were investigated during the second quarter of year 3, although only one case involves a low-speed impact where the injuries can absolutely be attributed to the energy of the air bag

Vehicle	Driver Age, Gender, Height, Mass	Belt Use and Type	Air bag Tether	CDC	Delta V and EBS (mph)	Upper Extremity Injuries
94 Chevrolet Camaro	49 M 188 cm 114 kg	3 pt	no	11FYEW4	26 ΔV 27 EBS	R distal radius fx R distal ulna fx R olecranon fx
91 Dodge Spirit	73 F 173 cm 64 kg	3 pt	yes	12FDEW3	30 EBS	R radius fx, open R ulna fx, open
93 Nissan Maxima	30 F 160 cm 64 kg	2 pt (shoulder belt only)	yes	12FDEW2	19 ΔV	L mid-shaft ulna fx, comminuted
96 Olds Cutlass Supreme SL	75 F 163 cm 54 kg	3 pt	no	01FZEW1	10 EBS	R distal radius fx

Three of the four drivers sustained a fractured radius, two sustained an ulna fracture, and one sustained an olecranon fracture. The fourth driver sustained an ulna fracture only. A number of these fracture types have been generated in the laboratory testing.

An abstract has been submitted to the 1998 Experimental Safety Vehicles (ESV) Conference. The results of the modeling and crash investigation efforts are to be presented at the meeting, and any available inertia or fling testing data would be included as well.

Project D.5: Investigation of Alternative Data Compression/Transmission Methodologies

Crash dummies have ever increasing amounts of instrumentation leading to umbilical cables of increasing size. These larger, more massive cables are reaching the point where they can interfere with dummy kinematics, film coverage, etc. This project will look at alternative methods of capturing and transmitting data from transducers to computer memory, including, but not limited to fiber optics, multiplexing, radio-link, and/or on-board data storage; and it will endeavor to develop a prototype system capable of handling, at a minimum, 128 independent channels of simultaneous data.

The principal investigator of this project resigned as an employee of GM. GM will work with NHTSA technical staff to determine whether the project should continue within GM or be contracted outside of GM.

The spine box of a Hybrid III dummy was modified in order to mount the data acquisitions system within the dummy. A cabling harness is required before bench testing of all modes of communication can begin.

Project D.6: This project has been completed and the final report submitted to NHTSA.

Project D. 7: Development and Dynamic Testing of a Second-Generation Pregnant Abdomen

A second-generation pregnant abdomen with a simulatedfetus, uterus and uteroplacental interface will be developed based on results from other portions of this study, including human measurements taken in the delivery room and anthropometric measures taken in the simulated motor-vehicle environment, The new abdomen design will also take advantage ofprogress on the advanced abdomen and instrumentation now under development at General Motors.

Testing of the new pregnant abdomen and early prototypes will consist of both component testing as well as whole-body (i.e., in-dummy testing). These tests will be performed using UMTRI impact testfacilities, including the impact rebound sled and the pendulum impactor. Separate component testing will also be used to evaluate the new pregnant abdomen. Separate component testing will also be used to evaluate any special abdomen instrumentation. Abdomen testing would be conducted throughout the abdomen-development process and upon completion of the final prototype.

Lawrence W. Schneider, Ph.D., of the University of Michigan Transportation Research Institute, is the principal investigator for this project.

Both physical and finite element models are under development for use in understanding the mechanisms of placental abruption and the response of the pregnant abdomen to impact. For the physical models, preliminary materials and adhesives for assembling fluid-filled bladders with disks attached to the inner wall were selected.

Finite element models of a pregnant uterus are being developed by First Technology Safety Systems, Inc. The first baseline utero-placenta concept model was developed to determine the feasibility of modeling large deformation impacts to a highly elastic structure/fluid complex. The model represents a seven-month pregnant uterus. Initial assumptions were that no fluid flow takes place, and that the amniotic fluid could be represented as an incompressible elastic fluid. The first model includes simplified geometric shapes to represent a uterus, placenta, amniotic fluid, and fetus. The uterus and placenta elastic moduli were initially estimated to be 10 kPa and 50 kPa, respectively. The fetus is represented by a rectangular block of fluid at a higher density than the surrounding amniotic fluid. Impact simulations have involved dropping the "free-floating" uterus onto a rigid plane from a height of 0.5 m. The model proved to be stable, but the extreme amount of deformation indicated by the fetus needs to be represented by a non-fluidic element.

In the second concept model, the fetus was represented by a sphere connected to an ellipsoid, with both pieces modeled as an elastic material similar in stiffness to the values used for the placenta. Vertical drops to a flat surface at angles of 0°, 30° and 90° were simulated. The assumption of no fluid flow was no longer valid for large deformations, since the fetal representation is expected to move into contact with the uterus and placenta, and displaces some of the amniotic fluid. Fluid flow was simulated by use of the LS-DYNA air bag material to give a sliding contact interface between the amniotic fluid and the fetus. The pressure and shear stresses were monitored at the utero-placental interface, and showed two distinct peaks during the deformation. The first peak occurred early in the event and was caused by local deformation of the uterine wall, which, being incompressible, deformed radially perpendicular to the impact direction. The relative inelasticity of the placenta restrained this motion and generated shear stresses. The second peak occurred as the fetus impacted the placenta and caused further compression of the uterine wall.

The next step in improving the concept models involves providing more realistic boundary and loading conditions. An MRI of a pregnant woman was digitized and incorporated into a three-dimensional image of the abdominal region. The pelvis and spine were modeled, and the concept uterus-placenta model was aligned with the uterus outline. Including adjacent body parts around the uterus will limit the amount the uterus can deform under impact. The geometry of the pelvis needed to be shifted to a seating posture, since the MRI was taken in a supine posture. Information regarding pelvic angle in the automotive posture is being obtained from Project D.10. Additional pregnant MRIs are being sought to provide better information regarding the position of the uterus with regard to other abdominal and thoracic structures and organs. After improving the boundary conditions, loading conditions from the seat belt and steering wheel will be simulated.

Project 0.8: Data Acquisition for Development of a Uteroplacental Interface for the Second-Generation Pregnant Abdomen

Because the mechanism ofpregnancy loss resultingfrom motor vehicle crashes is most frequently a result of separation of the placenta from the uterus (abruptio placentae), it is critical thatfuture iterations of a pregnant anthropomorphic test device incorporate a uteroplacental interface (UPI). Development of this interface will require an improved understanding of the adhesive and cohesive factors of the UPI, as well as the type and magnitude offorce necessary to disrupt this interface, as no known data currently exists. Using a force transducer coupled to an ultrasound monitor, force displacement curves will be generated in human pregnancies after delivery of the infant. This procedure (known as the Crudea maneuver) isperformedfollowing delivery of the infant to assist in placental delivery, andposes no significant increased risk to the pregnant woman. These measurements will be utilized to develop a UPI with reasonable biofidelity for the advanced pregnant anthropometric test device.

Mark Pearlman, M.D., of the University of Michigan Medical Center, is the principal investigator for this project.

The data concerning the indentation force-displacement behavior of the lower abdomen in two non-pregnant volunteers have been provided to First Technology Safety Systems (FTSS) for use in developing the finite element model. Force was measured normal to the skin surface in the mid-sagittal plane, and delivered manually by Dr. Pearlman in a quasistatic mode using the custom-made force transducer. A non-contact, video-based system was developed for reading quasistatic displacements of the transducer tip which has a cross-sectional area similar to the base of the hand. The force-displacement relationship was measured under two conditions: (1) relaxed abdominal wall musculature, and (2) fully contracted abdominal wall musculature. In the third quarter of year 3, these tests will be conducted using two other indentor shapes (steering wheel segment, taut seat-belt segment) to measure the force-displacement behavior of the subject's abdomen, including pregnant patients. Indentor tip shapes have been fabricated.

The graduate student research assistant who was working on the tissue property tests graduated at the end of August. Another student was identified and is being trained on the MTS testing machine to perform the studies of uniaxial tensile tests on placental and uterine tissue. Testing is to start early in the third quarter of year 3 with the focus first on low rates and then high-rate biaxial testing. Ten placental and ten uterine specimens were harvested and frozen for these tests.

Additional patients were added to the database concerning the ultrasound studies of change in uterine wall thickness from the beginning of labor to the moment of uteroplacental separation. These tests provide estimates of the compressive strain in the uterine wall when the placenta separates. Results for tests with 11 women confirm the previous finding that the placenta separates at a circumferential strain of approximately 60%.

Project D.9: Investigations of Pregnancy Loss Resulting from Motor Vehicle Crashes

There is limited quantitative information available on the crash, vehicle and restraint conditions that result in injuries to pregnant women and unborn fetuses. It is therefore proposed that UMTRI's accident investigation team conduct in-depth investigations into crashes in which a pregnant driver has sustained abdomen andfetus-related injuries. These investigations will consist of in-depth measurements and documentation of the crash conditions, interior and exterior vehicle damage, and crash reconstructions using state-of-the-art software packages to estimate impact severities. It will also include detailed documentation of injuries to the mother and unborn child and, most importantly, documentation of the correlation between abdomen/fetus injuries and estimated occupant kinematics and contacts with restraint and vehicle components. A network of contacts with other accident investigation teams, emergency rooms, and trauma centers will be established to identify potential cases in a timely manner. While these data must be acquiredprospectively. through networking with local and regional hospitals, it is anticipated that between 10 and 20 cases, per year will be investigated

Lawrence W. Schneider, Ph.D., of the University of Michigan Transportation Research Institute, is the principal investigator for this project.

Investigations of crashes involving pregnant women continued during the second quarter of year 3. Thirteen additional crashes were identified; one became a major investigation, four became minor investigations, and the remaining eight were excluded for various reasons. Details on the one major case (both the vehicle and complete medical records were available) and four minor cases (the vehicle and/or complete medical records were not available) that were added to the database during the second quarter of year 3 are given in the following table. The major case is in bold type. By the end of the second quarter of year 3, 47 crashes had been identified, with a total of 23 major and minor investigations.

Impact Direction	Impact Severity	Occupant Position	Occupant Restraint	Gestational Age (wk)	Maternal Injuries	Fetal Outcome
front.	severe	right front	none	36+	major	No problems to date
side	**moderate**	**driver**	**3 pt. belt & air bag**	**20-23**	**minor**	**No problems to date**
front	moderate	driver	3 pt. belt & air bag	36+	moderate	No problems
rear	minor	driver	3 pt. belt only	36+	minor	Contractions stopped without intervention
side	severe	right front	3 pt. belt only	20-23	major (fatal)	Fetal loss

Impact severity is divided into minor (0-15 mph), moderate (15-30 mph) or severe (30+ mph). Maternal injuries are divided into minor (ISS<10), moderate (10>ISS<20) or major (ISS>20).

Project D. IO: Seated Anthropomehy During Pregnancy

The objective of the proposed study is to conduct a comprehensive investigation of the changes in body dimensions ofpregnant women over the period of gestation and the effects of these changes on restraint system fit and seat and body positioning in the automotive environment. Data collected in this study will provide important information concerningfetal injury potential due to seat belt and steering wheel loading during a frontal crash; as well as information necessary to design an improved abdomen for the pregnant test dummy.

This study will be conducted using an adjustable seating buck equipped with a sonic digitizer system that enables collection of three-dimensional coordinates of body landmarks, seat belt position andprofiles, and locations of vehicle components. The seating buck allows for quick and independent adjustment of seat height, steering wheel-to-pedal distance, pedal angles, steering wheel tilt angle, and seat cushion angle. An array of microphones and a sonic probe are used to collect the 3-D coordinates of identifiedpoints and contours on the subject, the restraint system, and the vehicle components. Digitizedpoints are retrieved by a dedicated PC and displayed on the computer monitor. The seating buck will be modified to include a three-point restraint system with adjustable installation geometry to accommodate different vehicle package configurations.

Lawrence W. Schneider, Ph.D., of the University of Michigan Transportation Research Institute, is the principal investigators for this project.

Subject recruitment and measurement sessions continued. By the end of the second quarter of year 3, 18 subjects had been recruited. All have completed the first measurement session, 10 have completed the second session, and three have completed the third session. Finding subjects in the shortest stature group proved more difficult. Additional incentives for participation were added, including free child care during testing and a gift certificate for a child safety seat. The following table summarizes some basic information on the subjects tested as of the end of the second quarter of year 3:

Subject Number	Age (years)	Stature (mm)	Weight (kg)	Expected Delivery Date
F0101	29	1531	56.8	3-21-98
F0102	18	1484	78.5	4-4-98
F0201	31	1600	62.6	1-29-98
F0202	30	1575	86.7	1-18-98
F0203	28	1564	69.9	3-8-98
F0301	29	1635	55.4	3-16-98
F0302	23	1610	67.6	3-3-98
F0303	36	1629	81.7	3-3-98
F0304	26	1630	53.1	3-7-98
F0305	28	1631	62.2	11-22-97
F0401	26	1670	69.9	11-22-97
F0402	24	1650	72.6	12-1-97
F0403	30	1657	88.1	2-22-98
F0501	36	1691	78.1	12-10-97
F0502	36	1759	65.4	12-25-97
F0503	29	1699	65.8	12-31-97
F0504	25	1718	72.2	1-1-98
F0505	25	1671	56.3	2-12-98

Methods for presenting three-dimensional plots of the subject contours and body landmarks in relation to vehicle components and belt restraints are being developed. In addition, distances and quantitative relationships between subject, vehicle, seat, and restraint positions for the different configurations, and across test sessions, are being determined and analyzed.

For the three subjects who completed three test sessions, no obvious trends in selected seat back angle or seat track position over the course of pregnancy are apparent. For these three subjects, steering wheel orientation and abdominal mid-line contour for each visit in two configurations were plotted. The minimum abdominal clearance is given in the following table for the four configurations in which these subjects were tested. Configurations 2 and 4 use a seat height of 270 mm, while configurations 5 and 7 use a seat height of 360 mm.

Configuration	Subject Number	Visit 1 < 14 Weeks	Visit 2 20-24 Weeks	Visit 3 28-32 Weeks
2	F0305	180	99	61
	F0401	162	138	80
	F0501	166	166	113
4	F0305	169	108	55
	F0401	143	135	83
	F0501	146	157	81
5	F0305	156	115	62
	F0401	171	127	67
	F0501	161	157	117
7	F0305	164	108	62
	F0401	173	126	72
	F0501	155	169	117

Subject F0305 did not change her steering wheel position as gestational age increased. Her mean abdominal clearance over the four conditions decreased from 167 mm to 60 mm between the first and third visits. Subject F0401 changed the steering wheel to be more upright in her third visit at the 270 mm seat height configuration. Her mean abdomen-to-wheel clearance decreased from 162 mm to 76 mm between the first and third visits. Subject F0501 changed her posture and seating position between the first and second visits, shifting rearward on the second visit and maintaining a similar level of abdominal clearance (mean clearances of 157 on the first visit and 162 on the second visit). On the third visit, her mean abdominal clearance measured 107 mm.

Project D. 11: Biofidelity of the Hybrid III Lumbar Spine

> *Tests will be conducted with volunteers or cadavers (depending on test conditions) to establish the biomechanicalproperties of the human lumbar spine.*

Albert I. King, Ph.D. and King H. Yang, Ph.D., of Wayne State University, are the principal investigators for this project.

During the second quarter of year 3, work concentrated on the completion of 24 combined load tests on the Hybrid III Lumbar Spine, as well as 200 cadaver tests on 10 human lumbar spine specimens. The cadaveric specimens were potted in auto body filler and tested according to protocols established in the preparation of the first cadaveric spine.

The protocol followed in the preparation of the cadaveric specimens is as follows. First, the vertebral columns were thawed and sections including T12 through L5 were removed. Remaining soft tissues, including disk material at the exposed ends, were removed to provide rigid interface for the potting material. At this point three cortical screws were attached to the specimen at each end to improve fixation in the potting material. Holes were drilled and tapped to avoid additional stresses.

The order of testing was chosen so that the least destructive tests were conducted first. All samples were tested first in quasistatic mode on an Instron materials testing machine, and then dynamically on a linear impactor first in single mode then in combined mode loading.

During the testing of the cadaveric spines, damage was progressively sustained by the specimens. This resulted in the premature retirement of some specimens prior to their complete testing. For this reason, the actual number of tests run varied. Specimen damage was most severe in the final stages during combined load testing with the application of static loads. Specifically, when 90 lb and 180 lb static loads were applied. It was decided during testing to forgo combined loading under 180 lb tension for cadaveric specimens in light of the likelihood of significant damage to the specimens. Many specimens did not survive complete testing due to intervertebral disk detachment and/or vertebral body fracture. Fractures were generally in the proximity of the potting interface, but were not limited to this area.

Upon initial assessment of the data, loading appears to be bimodal with an initial toe-in region followed by a low stiffness region, an increased stiffness region and a peak for all tests of cadaveric specimens. Data processing continues.

I.E. Burn & Trauma Research

This report describes activities in the three trauma centers funded by General Motors under this project.

Project E. I: Fund Data Collection on Crashes, Injuries, and Their Consequences

> *The intent of this project is to establish a trauma network to collect crash and injury data, which will include geographic and demographic data, crash scene data, prehospital and hospital medical data, and rehabilitation and residual medical condition data. It is expected that the resulting database willfacilitate improvements in both the delivery of acute medical care for burn and impact injuries and the engineering of vehicles. The data will be used for both retrospective andprospective studies, including EMS outcomes research.*
>
> *The centers funded by General Motors under this project, together with the four centers funded by the NHTSA, will collect vehicle crash and injury data from locations in the east, mid-west, and west. It is expected that all participating trauma centers will use the Automated Data Processing System developed in Project E.3 (Establish a Networkfor Data Collection on Crashes, Injuries and Their Consequences).*

Harborview Injury Prevention & Research Center

David C. Grossman, M.D., of Harborview Injury Prevention & Research Center, is the principal investigator for this project.

Monthly clinical team meetings were held with Harborview clinicians and medical examiners to discuss the mechanics of occupant injuries in the cases being considered. NASS training was completed by the Harborview crash investigator and he started conducting some crash investigations independently. However, due to his junior status, Harborview continued to retain KLD Associates for consultation as to specific crash investigations.

Diego

Dr. David Hoyt and Dr. Brent Eastman of San Diego County Trauma System are the principal investigators for this project.

San Diego County's area-wide QANet system has proven to be an efficient and timesaving mechanism to track all motor vehicle patients transported to participating trauma centers. On a daily basis, occupants are identified and exclusion reasons are documented. Researchers at the hospitals investigate those cases involving potential candidates.

Although clinical, social and demographic data points had not been finalized by CIREN, the San Diego County team reviewed local data elements and revised the data collection instrument. Plans were formulated to conduct on-going quality assurance sessions to ensure consistent data collection at all participating trauma centers in San Diego County.

San Diego's crash investigator completed his NASS training and investigated seven cases during the second quarter of year 3. He also initiated and strengthened communications with local crash investigators, law enforcement agencies, and tow-yard operators.

Investigative Review Board documentation was completed and submitted to three additional trauma centers in San Diego County. The San Diego Project Manager and research nurses began to develop an educational curriculum to orient the new trauma centers to the project.

Monthly team meetings were held with the principal investigators, project manager, crash investigator, Medical Examiner and hospital physicians and research nurses to review crash case data.

University of Michigan

Stewart C. Wang, M.D., Ph.D., of the University of Michigan Trauma Burn Center, is the principal investigator for this project.

During the second quarter of year 3, the University of Michigan continued to collect cases under the existing criteria. Internal meetings were held bi-weekly with the local research team to review information for each case.

The University of Michigan made preparations to host the October 20, 1997 CIREN conference at the University. This entailed close contact with NHTSA personnel regarding the format and program for the meeting. Selected cases were sent to Harborview, Miami, and the University of Medicine and Dentistry in New Jersey for inclusion in their meeting presentations.

A CD recorder was purchased and installed to improve archiving capability, as well as the ability to share cases with other centers.

Dr. William Alarcon was added to the team of investigators in Ann Arbor. He has completed three years of surgical training and will spend three to four years doing research in the Trauma Burn Center at the University of Michigan.

Case Data Provided by the Trauma Centers Funded by General Motors Under This Project:

:ase Vehicle & mpact Direction	Case Occupant, Seat Position, & Restraint Used	Injuries
992 Volkswagen etta rontal impact	69 M, 5'7", 140 lb. driver 3 pt. belt	L femur fx, condyle, closed L femur fx, supracondyle, closed R patella fx, closed R tibia fx, proximal, closed Thorax contusion, anterior wall
993 Subaru :urbo-wagon eft side impact	41 F, 5'6", 194 lb. driver 3 pt. belt	Sacrum/coccyx fx, closed L pubis fx, closed L femur fx, shaft, closed L hip/thigh laceration
991 Jaguar XJR rontal impact	25 F, 5'7", 220 lb. right front passenger 3 pt. belt	Lip laceration R acetabulum fx R forearm laceration
991 Geo Prism rontal impact	33 F, 5'6", 260 lb. driver 3 pt. belt	L upper lip laceration R femur fx R femur fx, greater trochanter R fibula fx, proximal
996 Ford Escort eft side impact	20 M, 5'7", 182 lb. driver 3 pt. belt	Fatality Head subgaleal hemorrhage R frontal bone fx Bilateral parietal bone fxs Bilateral temporal bone fxs Bilateral orbital roof fxs Sphenoid bone fx Cribiform plate fx R petrous ridge fx Pituitary fossa fx L sphenoid bone fx, anterior Brain stem avulsion Spinal cord transection, C3-C4 Vertebral fxs (T10-T11), dislocation R ventricle laceration Pericardium laceration L rib fxs, ribs 1-6 anterior, ribs 2-8 posterior L hemidiaphram laceration L kidney transection Bladder laceration Spleen lacerations, multiple Pubic symphysis separation R superior pubic ramus fx R/L sacroiliac joints fx
.994 Toyota :orolla ight side impact	10 M, 4'9", 89 lb. right front passenger 3 pt. belt & air bag	R subarachnoid hemorrhage, closed L clavicle fx, shaft, closed Spleen parenchyma laceration Scalp laceration @ hairline
995 Nissan 'athfinder rontal impact	30 M, 5'6", 175 lb. driver 3 pt. belt	Heart contusion, closed

:ase Vehicle & mpact Direction	Case Occupant, Seat Position, & Restraint Used	Injuries
992 Toyota :orolla rontal impact	30 F, 5'8", 172 lb. driver 3 pt. belt	Fatality R skull fx, parieto/occipital L skull fx, parietal/frontal Basal skull fx Subarachnoid hematoma, parietal Brain contusions, midbrain and pons Cerebral cortex laceration R occipital subgaleal hemorrhage L occipital scalp focal hemorrhage Face & forehead contusions L ear contusion Mandible fxs L ribs 4 & 5 fxs, posterior L lung contusion, focal R clavicle fx L femur fx, mid to distal L arm contusion L wrist contusion R hand abrasion
993 Mercedes 90E rontal impact	62 F, 5'7", 149 lb. driver 3 pt. belt & air bag	Lower lip laceration L clavicle fx, shaft, closed L tibia fx, shaft, closed L malleolus fx, lateral, closed L knee/leg laceration, degloving
996 Chevrolet ;-10 Pickup ight side impact	22 F, 5'2", 120 lb. driver 3 pt. belt & air bag	Concussion Neck sprain L thorax contusion, upper anterior Bilateral thumb subluxation, at cuniform metacarpal junct. R medial cuniform fx, Grade II, open R extensor brevis/longis ligament lacerations L ankle sprain
993 Honda Civic eft side impact	14 M, 5'6", 130 lb. driver air bag only	L radius fx, distal neck, closed L femur fx, shaft, closed
992 Plymouth ,aser rontal impact	22 M, 5'7", 115 lb. right front passenger 3 pt. belt	CI brain laceration/contusion, no coma Neck abrasion Neck contusions, multiple Thorax contusion Heart contusion, closed
.993 Chevrolet :orsica rontal impact	77 F, 5'3", 151 lb. driver 3 pt. belt & air bag	Fatality Subarachnoid hemorrhage Subdural hematoma L parietal scalp contusion L forehead contusion R face abrasion

Case Vehicle & Impact Direction	Case Occupant, Seat Position, & Restraint Used	Injuries
1993 Mazda MPV right side impact	7 M, 4'0", 72 lb. rear middle passenger lap belt only	Cerebral contusion
1990 Plymouth Voyager right side impact frontal impact	62 F, 5'4", 112 lb. driver 3 pt. belt	Lip laceration Sternum fx L upper arm contusion R knee contusion
1990 Plymouth Voyager right side impact frontal impact	58 M, 5'10", 180 lb. right rear passenger 3 pt. belt	Mesenteric contusion
1990 Chevrolet Corvette side impact	51 M, 6'3", 245 lb. driver 3 pt. belt & air bag	C4-C5 Ligament disruption w/disc herniation Quadriplegia, C5
1993 Mercury Topaz left side impact front impact right side impact	39 F, 5'7", 143 lb. driver 3 pt. belt	Liver laceration, massive Pelvis retroperitoneal hematoma L pubic fx, with SI widening L acetabulum fx, closed
1993 Nissan Sentra frontal impact	30 F, 5'4", 120 lb. driver 3 pt. belt	Pancreas laceration, superior border of head Spleen rupture, complex, lacerations extending into hilum R retroperitoneal hematoma R perinephric hematoma
1997 BMW 328i frontal impact	22 F, 5'6", 130 lb. right rear passenger 3 pt. belt	R eyebrow laceration Lip laceration, upper Teeth loosened, 4 front upper teeth L5 fx, burst L middle finger sprain

Case Vehicle & Impact Direction	Case Occupant, Seat Position, & Restraint Used	Injuries
1993 Mazda MX6 frontal impact	41 F, 5'5", 166 lb. driver 3 pt. belt & air bag	Fatality Atlanto-occipital joint fx, dislocation C1-C2 transection, complete Loss of consciousness, fixed and dilated pupils Face abrasions (eyelid, nose, R cheek, R mandible, chin) R ventricle laceration Pericardial sac laceration R ribs 3-5 fx Bilateral hemothorax Bilateral pulmonary contusion Bilateral L breasts contusions, multiple 1/4" to 1/2" dia. R kidney laceration Renal vein laceration Mesentery hematoma Liver lacerations, multiple Spleen laceration Abdomen contusions, multiple, primarily on R side R upper arm contusion, inner aspect R hand contusion, posterior L forearm laceration, posterior L hand & wrist contusions, posterior R lower leg laceration, deep, circular Bilateral thigh contusions, anterior & inner, multiple Bilateral leg contusions, anterior & inner, multiple Bilateral ankle contusions, around ankles
1990 Toyota Corolla DX right side impact	47 F, 5'4", 105 lb. driver belt use unknown	Loss of consciousness, < 1 hour R face lacerations, above eyebrow, chin L cheek contusion, lateral to nose L arm contusion, upper inner aspect R arm contusion, upper lateral aspect, multiple R shoulder contusion, posterior R clavicle fx R ribs 3-7 fx, pneumothorax L knee contusion, medial L leg contusion, just below knee R leg lacerations, anterior lateral surface
1991 Nissan NX 2000 frontal impact	19 M, 5'10", 140 lb. driver 3 pt. belt & air bag	R face laceration, just below eye L thumb sprain R acetabulum fx L thigh contusion, medial aspect R thigh contusion, inner aspect R thigh contusion, anterior to lateral surface R leg contusion, anterior, just below knee R ankle contusion, outer aspect R foot sprain

Case Vehicle & Impact Direction	Case Occupant, Seat Position, & Restraint Used	Injuries
1991 Nissan NX 2000 Frontal impact	19 M, 6'2", 180 lb. right front passenger 3 pt. belt	Loss of consciousness, < 1 hour Neck abrasion, R side, posterior to anterior Forehead abrasion, upper, just R of mid line R hand lacerations, base of small finger to wrist, multiple L hand lacerations, index finger & thumb to wrist, multiple Cecum perforated Colon laceration R flank contusion L knee laceration R fibula fx, distal R talus fx
1991 Mitsubishi Galant left side impact	66 F, 5'7", 138 lb. driver 3 pt. belt	Fatality Neck abrasion Neck laceration, lateral prominence of larynx L ribs 1-3 & 4-9 fx R ribs 1-6 fx L lung laceration, upper lobe L lung contusion L shoulder ecchymosis, superior, extending to L neck R breast abrasions, upper medial quadrant Spleen lacerations, multiple Retroperitoneal hematoma, extensive L hemipelvic fx
1991 Ford Pony/Escort right side impact	36 F, 5'3", 171 lb. 6 months pregnant right front passenger 3 pt. belt	Fatality Fetal Loss Odontoid fx, with laceration, spinal cord transection Uncal herniation R neck and jaw abrasions, severe R chest abrasions Iliac crest abrasion, anterior
1990 Cadillac Deville frontal impact	77 M, 6'1", 191 lb. driver 3 pt. belt & air bag	Loss of consciousness, < 1 hour L chest ecchymosis, left and sternal area R acetabulum fx L tibia fx, plateau, comminuted

;ase Vehicle & mpact Direction	Case Occupant, Seat Position, & Restraint Used	Injuries
996 Chevrolet ;-10 Pickup 4X2 eft side impact	20 M, 5'10", 156 lb. driver 3 pt. belt	Fatality Basal skull fx, hinge-gaping, closed Subarachnoid hemorrhage, cerebellum Brain stem laceration, superficial L face lacerations, jaw and chin Aorta transection Bilateral lung contusions Sternum fx, at rib 1 R ribs 3-6 fx L hemothorax R chest abrasions, above nipple L chest abrasion, lateral aspect in axillary line Spleen lacerations, multiple Liver lacerations, multiple Bladder laceration, rupture R suprapubic ecchymosis L ulna fx, proximal at elbow L arm lacerations, at elbow R arm abrasions, upper and dorsal near axilla L humerus fx, mid shaft L femur fx, mid shaft, closed Bilateral leg abrasions, multiple
1996 Chevrolet S-10 Pickup 4X2 left side impact	24 M, 5'7", 176 lb. right front passenger 3 pt. belt	Fatality Cerebrum petechiae, NFS Cerebellum petechiae, NFS Brain stem petechiae Brain stem subarachnoid hemorrhage, upper Brain stem transection Brain diffuse axonal injury Scalp lacerations, right temporal Atlanto-occipital dislocation Cervical spine crush with cord injury R neck ecchymosis L neck ecchymosis, from ear to shoulder L face lacerations, cheek, chin and ear R shoulder laceration L rib fxs, ribs 2-9 posterior and ribs 5-8 lateral L hemidiaphragm laceration Chest ecchymosis, mid Mesentery lacerations, multiple, small, superficial, NFS R thigh ecchymosis L hip ecchymosis, lateral

:ase Vehicle & mpact Direction	Case Occupant, Seat Position, & Restraint Used	Injuries
:996 Chevrolet 3-10 Pickup 4X2 eft side impact	25 M, 5', 106 lb. right rear passenger lap belt only	Loss of consciousness, < 1 hour R forehead laceration R arm abrasion L radius dislocation, head L ulna fx, proximal L radial nerve injury R chest abrasion, lateral L kidney fx, grade IV L hip hematoma, lateral L femur fx, mid shaft L thigh hematoma, lateral
:990 Volvo '40 GLE Wagon eft side impact	16 M, 5'8", 158 lb. driver 3 pt. belt	Scalp laceration, top of head, mid line Spleen contusion L forearm abrasion
:990 Honda :ivic Sedan eft side impact	53 M, 5' 8", 185 lb. driver 2 pt. shoulder belt only	Loss of consciousness, < 24 hours Basilar skull fx L frontal sinus fx L sphenoid sinus fx, anterior L orbit fx, comminuted, blowout R orbit fx Nasal fx, comminuted R mandible fx L face lacerations, above and within eyebrow, lower cheek Bilateral face contusions, under both eyes R nose laceration, lateral L ribs 2-4 fx, posterior L lung contusion L arm contusion, upper and lower, inner aspect L arm abrasion, upper, lateral L forearm abrasions and contusions, multiple L hip contusion
:990 Mitsubishi :alant 'rontal impact	36 F, 5'6", 117 lb. driver 2 pt. lap belt 2 pt. shoulder belt	Maxilla laceration, complex gingival avulsion Bilateral nasal fx, non-displaced Neck strain Face abrasion Face contusion Chest contusion, lower sternum L arm contusion Spleen lacerations, 2, ≥3 cm deep with free fluid Lumbar spine strain Bilateral knee contusions
:993 Mazda 626 'rontal impact	49 M, 5'5", 134 lb. driver air bag only	Fatality (preliminary autopsy findings listed below) Cervical fxs Sternum fx Heart lesions R hemothorax

Case Vehicle & Impact Direction	Case Occupant, Seat Position, & Restraint Used	Injuries
1992 Saturn SL2 frontal impact	30 F, 5'9", 205 lb. pregnant driver 2 pt. lap belt 2 pt. shoulder belt	Traumatic brain injury L orbital wall fx Teeth 9 & 25 fxs Teeth 6-8 avulsion Gingival laceration Placental abruption with fetal loss L femur fx, open R fibula fx, head Bilateral tibia plateau fxs R calcaneous fx
1995 Ford F-150 pickup frontal impact	55 M, 5'9", 201 lb. driver 3 pt. belt & air bag	L2 fx, transverse process Pelvic fx, open book R sacral body fx and pubic diastasis R femur fx R fibula fx, neck R talus fxs
1992 Oldsmobile Achieva frontal impact	22 F, 5'2", 115 lb. right front passenger 3 pt. belt	R orbit fx, blowout Nasal bone fx Nasal base fx, comminuted C2 fx, lamina L rib 6 fx, posterior L radius fx, distal, metadiaphyseal L ulna fx, styloid
1990 Ford Probe offset frontal	56 M, 249 lb. driver 2 pt. shoulder belt	L1 fx, body extending into R pedicle, comminuted R L2 and L3 fxs, transverse process L femur fx R 1st metatarsal fx R radius fx, distal, Colles fx R ulnar fx, styloid L tibia fx, open grade II
1997 Ford Taurus rear impact	66 F, 5'2", 181 lb. driver air bag only	Subarachnoid hemorrhage R parietal lobe hemorrhage Interventricular hemorrhage, in R occipital horn Frontal lobe hemorrhage Bilateral rib fxs, multiple lower ribs Left femur fx, medial femoral condyle L3 fx, R transverse process, minimally displaced
1992 Saturn SC2 frontal impact	21 F, 5'10", 137 lb. driver 2 pt. shoulder belt only	Both lips lacerations R globe rupture Nasal bone fx R maxillary sinus fx R pneumothorax L radius fx, open L ulna fx, open, grade III Spleen laceration, grade III R talus fx, avulsion

Case Vehicle & Impact Direction	Case Occupant, Seat Position, & Restraint Used	Injuries
1992 Saturn SC2 frontal impact	24 F, 5'8", 123 lb. right front passenger 2 pt. shoulder belt only	R clavicle fx L ribs 4-6 fx, anterior/lateral R rib 3 fx, anterior Bilateral pneumothorax Bilateral chest wall contusions and abrasions
1996 Saturn SL2 frontal impact	75 F, 5'1", 187 lb. right front passenger 3 pt. belt & air bag	C2 fx, superior articular facet R rib 5 fx, with R lung contusion Mesentery hematoma Peri-duodenal hematoma R acetabulum fx, displaced, crescent-type with ileum & posterior pelvic disruption R tibial plateau fx, displaced Bilateral tibia fx, pilon R ulna fx R upper arm degloving R wrist degloving
1994 Ford Probe frontal impact	20 M, 6', 203 lb. right front passenger	L femur fx R 4th metacarpal laceration
1993 Jeep Cherokee frontal impact	45 M, 6', 205 lb. *driver* 3 pt. belt	R calcaneal fx, interarticular Teeth avulsions, anterior R mandible fx, subcondylar

Project E.2: Fund Research in Burn and Impact Trauma Mechanisms and Treatment

The biology of burn injuries and acute lung injuries, and their interaction in suppressing the immune system, will be studied.

Sub-Project E.2 (a): Lung Responses Following Motor Vehicular Trauma and Cutaneous Thermal Injury

Stewart C. Wang, M.D., Ph.D., of the University of Michigan Trauma Burn Center, is the principal investigator for this sub-project.

During the second quarter of year 3, patient recruitments increased and a large number of clinical samples were obtained for examination of cytokine production at the mRNA and protein levels. It was estimated that if sample accrual continues at the increased rate, the collection of samples for the first series of cytokine mRNA analysis will be completed during the third quarter of year 3. At that point, in-depth analysis of cytokine profiles during the burn injury responses are to begin.

During the second quarter of year 3, the number of cytokine and housekeeping gene mRNAs which can be assayed quantitatively by the Perkin Elmer TaqMan fluorescent PCR system was expanded.

Sub-Project E.2 (b): Wound Responses After Thermal Injury

Stewart C. Wang, M.D., Ph.D., of the University of Michigan Trauma Burn Center, is the principal investigator for this sub-project.

Efforts during the second quarter of year 3 were directed at continued recruitment of patients into the study. At the same time, the cytokine mRNAs which can be assayed using the TaqMan Fluorescent PCR system were expanded.

During the third quarter of year 3, the research is to be directed at defining the pattern and intensity of cytokine production within the lungs of patients who sustained blunt trauma or thermal injury. To determine if a lung's cytokine expression to trauma and burn injury alters local immunological function, the systemic and lung immune cell functions will be compared.

Project E.3: Establish a Network for Data Collection on Crashes, Injuries and Their Consequences

This project will fund the development of an automated data processing (A DP) system for the four NHTSA-funded trauma centers and the three centers funded by General Motors under Project E. I (Fund Data Collection on Crashes, Injuries, and Their Consequences). The ADP needs of the trauma network will be evaluated. The manner of collecting, storing and retrieving data in the trauma network will be compatible with the NASS retrieval electronic imaging system. The resulting hardware/software system may be provided to selected trauma centers.

Santo LaTores, of the Volpe National Transportation Systems Center, is expected to be contract manager for this project.

On September 4, 1997, NHTSA concurred with the Statement of Work for Project E.3 for years 3 and 4. The GM/Volpe contract was signed on September 30, 1997 by GM, and plans were made for Volpe to sign the contract during the third quarter of year 3.

I.F. Computer Modeling

Project F.1: Further Development of Head/Brain Models

> *The research effort in the first two years will be continued. Using a new simplified physical model and more accurate testing equipment and instrumentation (e.g., impact tolerant displacement transducer, high speed movies, and extensive pressure transducers), further experiments will be performed to ensure the validity and accuracy of the mathematical responses of the original experiments. The new experiments will also allow parametric studies of material properties and other finite element techniques to further assist the modeling of the bilateral brain model. The results of these efforts will be used to produce an optimized analysis of the original experiments for the purpose of defining tissue level injury criteria for the types of injuries produced in these experiments.*

Kazunari Ueno, Ph.D., of GM Safety Research, is the principal investigator for this project.

Impactor-to-brain contact and skull-to-brain contact are the two contacts defined in the model. Different contact types were investigated for these contacts to find the one which best represents the expected response. Appropriate values for contact thickness, contact stiffness and contact speed were also chosen.

Parameter studies were conducted with the elastic modulus set equal to 0.48, 0.24, 0.18 and 0.12 MPa. No results were obtained when the elastic modulus was set to 0.12 MPa because the simulation degenerated into negative volume elements. Contact forces generated by the models ranged from 32 N to 11 N for elastic modulus values of 0.48 MPa and 0.18 MPa, respectively. A contact force of 8 N was measured experimentally. Pressure at a central location of the gel ranged from 65 kPa to 35 kPa for elastic modulus values of 0.48 MPa and 0.18 MPa, respectively. The peak pressure measured experimentally was 15 kPa.

The pressure-time history generated by the model exhibited a 2-5 kHz noise, which may have resulted from a pressure wave. Experimentally, this frequency of noise was generally not observed. The contact force-time history generated by the model also exhibited noise. This may have been the result of contact element instability. Shear stress-time histories were smooth and relatively free of noise.

Models will be further exercised to optimize the elastic modulus over a number of different test conditions.

Project F.2: Development of Head/Neck Models

The research effort in the first two years will be continued. The finite element (FE) and lumpedparameter (LP) head/neck models will be further developed, especially in the area of biological material characterization. Test data from the literature and mechanical properties sub-project will be used to develop accurate representation of the soft tissues in the cervical spine. Muscle elements will be added to the FE model and enhanced in the LP model based on the anatomical data obtained from the impulsive loading response sub-project and the muscle model that will be developed in the Dyna3D code. Model validation will also continue using the cervical spine and whole body test data found in the literature.

Sub-Project F.2 (a): Development of a Three-Dimensional Finite Element Head/Neck Model for Injury Analysis

Yih-Charng Deng, Ph.D., of GM Body Engineering and Integration Research, is the principal investigator for this sub-project.

Work with Livermore Software Technology Corporation (LSTC) has begun to improve material models in the DYNA3D code for modeling the nonlinear anisotropic behavior of the annulus fibrosis. Enhancements were implemented for the orthotropic material (Type 40) to allow nonlinear curve input for the Young's modulus and shear modulus in each material direction. Using a theoretical formulation developed earlier and test data found in the literature, the identification of material constants in each material direction and testing of a revised model has begun.

Fifteen pairs of neck muscles were incorporated into the head/cervical spine model. These muscle models are based on those in the head/neck model developed by Deng and Goldsmith (1987) with three-point representation for the attachment and curvature. These muscle elements were modeled by the nonlinear spring feature in DYNA3D based on characteristics used in Deng and Goldsmith's model. After the muscle model development in DYNA3D (Sub-Project F.2 (e)) is complete, more rigorous muscle passive and active behavior will be implemented.

Using the head/neck model (with muscles) the Naval BioDynamics Laboratory (NBDL) human volunteer test was simulated. The first attempt simulated the 7.4 G frontal impact used by Deng and Goldsmith. Results from initial simulation runs are encouraging. However, there are issues regarding boundary conditions, soft tissue material model stabilities for large deformation, etc. These issues are currently being investigated.

Sub-Project F.2 (b): An Improved, Validated Three-Dimensional Head/Neck Model for Injury Analysis

Ara Arabyan, Ph.D., of the University of Arizona, is the principal investigator for this sub-project.

During the second quarter of year 3, a more consistent scheme to model the passive muscle behavior was developed. This scheme uses a generic stress-strain relationship of the muscle and takes into account the physiological cross sectional area of each muscle, and the minimum and optimum sarcomere length reported in the literature for calculating the force-elongation response of each muscle element in the model.

Muscle contraction was also investigated in this quarter. Various scenarios of muscle activation were applied to the model to study the head/neck response: (a) muscle activation to sustain an upright head posture under gravity, (b) maximum muscle activation on the flexors, and (c) maximum muscle activation on the extensors. The model exhibited reasonable response patterns under the effect of these muscle concentrations. In case (a), the model achieved an equilibrium configuration close to the initial position of the original model. In cases (b) and (c), the extent of head rotation fell inside the range of rotation reported in the literature.

The current emphasis is on developing a sound muscle activation scheme for implementation in the impulsive loading conditions.

Sub-Project F.2 (c): The Biomechanical Effects of Cervical Spinal Musculature on the Head and Neck Response to Impulsive Loading

Barry Myers, M.D., Ph.D., of Duke University, is the principal investigator for this sub-project.

The dissection of a second cadaver was completed. Ligamentous spine landmarks were digitized. A third cadaver was obtained and fully dissected. The spatial data from this cadaver have been compiled. Sarcomere length data are complete, and fiber length data are nearing completion. This includes measurements of the hyoid muscle group defined in the first quarterly report of year 3.

Two new MRI scans were obtained, bringing the project total to six complete volume studies. In addition, the hyoid muscle group defined in the first quarterly report of year 3 was digitized on all four prior scans. The two new data sets will be downloaded and analyzed in the third quarter of year 3.

The updated cadaver dissection data were used to re-estimate the partitioning of muscle volumes from the MRI data sets for splenius capitis/cervicis, longisimus capitis/cervicis, longisimus capitis/anterior scalene, and the hyoid muscle groups.

Based on preliminary data available from the 5th, 50th, and 95th percentile subjects, dimensionless scale factors were developed to allow estimation of any anthropometric group given normative data (e.g., subject height). These results will be examined when sufficient data are available for meaningful statistical evaluation.

The rates at which data may be collected are rapidly increasing, owing in part to the time spent in developing the methodology over the initial 18 months of this project.

Sub-Project F.2 (d): Mechanical Properties of Cervical Spine Tissues

W. Thomas Edwards, Ph.D., of Syracuse University, is the principal investigator for this sub-project.

The pump controller and other connections for the Planar Testing Apparatus (PTA) were completed and checked. The software programs for controlling this testing machine and for data collection had to be completely rewritten. The programs were originally written in LabView version 2, which was replaced by version 4. Work on the PTA to upgrade and revise the software control programs continued. Most of the lower level A/D and D/A interfaces and the file I/O changes have been completed. Testing of the new program routines with the PTA hardware will begin during the third quarter of year 3.

A ligament stretch apparatus was constructed for tension tests of isolated cervical spine ligaments. This device was designed to stretch individual cervical spine ligaments from rest to a specified length at a constant velocity. A high rate of stretch was obtained in tests using an impact load.

An acceleration of approximately 1200 Gs is required to provide the sharp transition from the constant velocity displacement ramp to the fixed displacement. The original high accelerations produced unwanted vibrations during the first 300 ms. This was observed in the preliminary tests of an isolated human lumbar interspinous ligament. The frame was isolated from the floor by placing small amounts of deformable material between the falling weight and the test frame. This attempt to correct the problem was not adequate when the human cervical spine specimens were tested.

Several tests were made of the stretch response of human cervical spine tissues. Specimens were obtained from a male fresh-cadaver motion segment at the C6-C7 level. Specimens from the isolated interspinous ligaments (including the ligamentum flavum and the super-spinous ligaments), and from the isolated right and left facets were tested. These tension measurements showed oscillations, primarily in the load measurement, immediately following the velocity ramp at the beginning of relaxation.

Dynamic measurements were obtained form the Ligament Stretch Apparatus during simulated tests, following the drop of the weight. The responses from accelerometers placed at the load cell and at the base of the frame were compared to the load output measurement. Damped oscillations at 200 and 400 cps were found. The amplitude of the oscillations from the frame correlated with the load measurements. As expected, the lowest amplitudes were observed on the base plate. The measurements suggest that the load cell should be isolated from the falling weight (displacement-velocity) input. Modifications to place the load cell on separate support columns have begun. This should raise the frequency response of both the load cell supports and the weight-slider portions of the frame, and reduce the oscillations in the data.

Three channels of data are currently being collected. These are force, displacement, and time. The initial data rate was 1,000 samples/second (per channel) over the first second, decreasing to 8.3 samples/second through the remainder of the two-minute data collection period. The initial sampling rate is to be increased to 2000-5000 samples/second for better resolution.

Sub-Project F.2 (e): Development of a Muscle Model for Dyna3D.

Jeffrey A. Weiss, Ph.D., of the Orthopedic Biomechanics Institute, is the principal investigator for this sub-project.

The implementation of LS-DYNA3D is in progress, using the formulation and input format similar to that described in the MADYMO documentation. The FORTRAN subroutines in LLNL-DYNA3D that control the discrete element input, options, and force calculations have been decoded. The existing discrete element materials have been tested using a simple one-element velocity-controlled problem to ensure that they are working properly. An error in the coding for the I/O was identified and corrected in the existing code.

The input/output was implemented for the new Hill Model discrete element material model. This required modification of the current allocation for material parameters. It allowed 16 words of storage to be available for discrete element material parameters. The Hill Muscle Model is being implemented as Discrete Element Material #5. Input requires the specification of the parameters on Discrete Element Material cards 1 and 2.

Plans were made for the one-dimensional element to be completely implemented early in the third quarter of year 3. A simple one-dimensional MADYMO-type test problem will be used

Project F. 3: Develop Interactive Computer Software for Characterization of the Hazards Posed by Heat and Exposure to Toxic Agents Associated With Fire

The research effort in the first two years will be continued. Models ofpost-crash vehicle fires will be developedfor an engine fire resulting from frontal crash and for a fuel-fed fire resulting from a rear impact. Four types of vehicles will be modeled: minivan, rear-drive coupe, front wheel drive sedan, and sport-utility vehicle. The models will incorporate relevant toxic gas concentrations and heat flux scenarios developed from the pyrolysis of vehicle exterior and interior materials. The vehicle interior will be monitoredfor the hazards to occupants posed by heat and toxic gases. The models will be benchmarked against the results of Project 8.3.

Sub-Project F.3 (a): Software for Characterization of the Hazards Posed by Heat and Exposure to Toxic Agents Associated With Fire

Kenneth A. Strom, Ph.D., of GM Safety Research, is the principal investigator for this sub-project.

The validation data for fire modeling consists of thermal measurements for seat occupant positions, and fire-induced pressures. From the thermal measurements, the potential for burn injury can be calculated. Reports on the mathematical transformation of the thermal data to heat flux, and hence, to burn potential are being prepared. From the pressure and temperature measurements, the fire pressure against the bulkhead and within the cabin can be established.

In order to model the effect of an engine fire on the occupants of a post-crash vehicle, a modeling domain (space to contain the vehicle and fire) has to be established that will meet the following criteria: (a) boundary conditions must allow air to flow into the region and fire products to freely exit, (b) fire properties that are consistent with experimental determination including proper convective and radiative heat release and release of fire products, (c) convective and radiative heating of the bulkhead, windshield and occupants, and (d) tracking of the fire products into the vehicle cabin.

Initial modeling efforts are focused on establishing pressure boundaries on the modeling domain that allow for the free flow of air into the domain and fire products out of the domain. These trials had limited success through the end of the second quarter of year 3.

For the second set of fire tests, the directional flame thermometers were rebuilt to be compatible with the new data collection system for Project B.3. The pressure transducers were rewired for the new data collection system and were calibrated for response to pressure change. New validation data are to be collected during the subsequent fire tests.

Sub-Project F.3 (b): Computer Modeling of Fire Spread from Engine to Passenger Compartments in Post-Crash Vehicle Fires

Jonathan R. Barnett, Ph.D., of Worcester Polytechnic Institute, is the principal investigator for this sub-project.

Worcester Polytechnic Institute submitted a draft report to GM on the suitability of the computational fluid dynamic (CFD) software TASCflow in modeling post-crash vehicle fire. The draft of the report was reviewed and commented on by the GM Project Manager, and returned for revision.

James A. Ierardi joined Dr. Barnett on the sub-project, as a replacement for Nathan Wittasek, M.S. Mr. Ierardi is modeling the problem of fire penetration from an engine compartment fire through a fractured windshield into the occupant compartment. Initial progress on the sub-project consisted of a background review of the literature on experimental car fires and the synthesis of a design fire for CFD modeling. The material properties of windshield and engine components were used to formulate a CFD model of engine compartment and intact windshield.

Project F.4: Experimental and Analytical Study of Transient Heat Loss to Air Bag Materials

*The research effort in **the first** two years will be continued. Study **of** transient heat loss to **airbag** during deployment and to the tank wall during an inflation tank test will be continued. Improvements will be made to the experimental setup for measuring the permeability and transient thermal response of **airbag** fabrics to allow for testing in higher temperature (i.e., to permit maximum fabric temperatures near 150 °C). Also, the numerical model will be revised to include the possibility ofmultidimensionalfw near the fabric surface, which will be developed to simulate the transient heat loss. For the **airbag** module and testing tank analysis using **both finite** element (FE) and lumped heat capacity (LHC) methods will be conducted. About 40 **airbag inflators** and modules will be tested with 64 k-type and k-type ultra-fine thermocouples. The measured **temperature-**time history will then be used to validate both FE and LHC methods and to determine heat transfer **coefficients**. Additional research will be conducted to characterize and model the aspiration and venting events **of** an aspirating inflator.*

Sub-Project F.4 (a): Transient Heat Transfer Between a Compressible Gas and a Porous or Nonporous Polymeric Layer

Massoud Kaviany, Ph.D., of the University of Michigan, is the principal investigator for this sub-project.

The test cell of the experimental apparatus was modified to allow transfer and/or parallel air flow. This modification allows the parallel air flow velocity to be varied from near 0 m/s to 10 m/s on the impermeable fabric. The direction of the parallel flow can now be adjusted angularly.

Vacuum pump evacuation of the resident air within the test cell prior to the test improved the heat-up rate from 400 msec to 80-100 msec. The ability to pull a vacuum throughout the test cell, and consequently the heat-up rate is limited by the seals in the solenoid valves. Evacuation of the test cell allows a temperature change of 200°K over a short initial time period.

Permanent thermocouple positions are being used to further standardize the test setup. This enhancement also dramatically decreases the down time to change fabrics. It also improves the response time of the fabric thermocouples, since the extra mass of the glue is no longer required *to* attach the thermocouple to the fabric.

The designs for these modifications were completed and the machining began.

A distributed one-dimensional model was developed that accounts for the radiation on the upstream and downstream surfaces, upstream and downstream convection, energy storage, and internal convection for permeable fabrics. From this model, the distributed transient thermal response across the fabric can be predicted.

The distributed model requires input of fabric properties, upstream (bag internal) gas properties, and three convection coefficients. Methods of determining proper values for these convection coefficients are being explored and evaluated with attention directed towards their physical meaning and the manner in which these coefficients can be functionally related to parameters already measured or determined in existing air bag deployment codes, such as internal bag pressure and temperature and inflator exit properties.

Sub-Project F.4 (b): Experiments and Simulation of Transient Heat Losses to Airbag Assembly and Discharge Tank During Inflation Process

Wen-Jei Yang, Ph.D., of the University of Michigan, is the principal investigator for this sub-project.

Tank wall temperature, tank gas temperature, and tank gas pressure were measured, and the discrete data were "best-fitted." A computer program with finite difference analysis implementing Colburn Analysis was constructed. In-wall temperature distribution, heat transfer coefficient, total mass and mass discharge rate were calculated. Characteristic length and velocity to be used in the Colburn analysis were obtained from dimensional analysis. Subsequently, Reynold's Number, Nusselt's Number, and the coefficient C were obtained.

Commercially available, ultra-fast response thermocouples (E12-3-K, NANMAC, Framingham, MA) were purchased to replace the existing thermocouples (OMEGA KMTSS-020-G). The existing thermocouples, which had a point tip, could not be securely placed at the point of measurement. The new thermocouples, with the sensing tip that can be machined to any shape, can be mounted onto the tank wall, flush within 25 μm. They will drastically reduce the thermal contact resistance between the wall and thermocouple junction tip, resulting in more reliable temperature readings. Also, the ultra-fast response time of the new thermocouples are capable of more precise readings at rates up to 10,000 readings per second, which will increase the experimental flexibility.

The washer plug was redesigned to accompany the new thermocouples. Instead of drilling a thin hole to place the point tip thermocouple, a 1/8" diameter hole is drilled to a depth of 1 mm from the flat surface, which will approximate the interior tank surface. The bottom of the hole is machined to a flat surface for the flat probe head of the new thermocouples. At the back surface, the hole exit is machined to 1/8" NTP to allow the adjustable fitting screw on the thermocouple to lock the thermocouple securely into a fixed position.

The rest of the experimental set up, such as tank, pressure transducers, amplifiers, gas measurement thermocouple junctions, and the data acquisition systems remain unchanged.

Three different kinds of air bag inflators are used to obtain the data for different deployment conditions. This is necessary to achieve the best correlation.

Sub-Project F.4 (c): Analysis, Modeling and Integration

J. T. Wang, Ph.D., of GM Body Engineering and Integration Research, is the principal investigator for this sub-project.

Work is in progress on this project, and any expenditures (including oversight and administrative expenses) during the second quarter of year 3 will be reported in the financial reports submitted to NHTSA after NHTSA has approved the statement of work of year 3.

A report on the Airbag Inflator Simulation Program (ISP) was drafted and was provided to GM for review.

A hybrid inflator simulation program was developed. This program treats the thermocouple events associated with ignition, flame spread, and propellant combustion of pyrotechnic events associated with ignition, flame spread, and propellant combustion of pyrotechnic air bag inflators. Modifications to adopt different inflator suppliers' input data are being developed.

Sub-Project F.4 (d): Quantitative Evaluation of Aspiring Airbag Inflators

P. B. Butler, Ph.D., and L. D. Chen, Ph.D., of the University of Iowa, are the principal investigators for this sub-project.

The primary focus of the work performed during the second quarter of year 3 was preliminary CFD modeling and cold-flow experiments. In addition, construction of the hot-firing test stand progressed to the firing stage pending air bag availability.

The construction of the test stand was completed. Several considerations including loudness and pressure during firing will be addressed after several test firings. In addition to the test stand, a control center was constructed out of similar materials. The control station provides an additional layer of protection for the experimenter and houses the data acquisition equipment. An ignition circuit was constructed according to specifications provided by Delphi Lighting Systems. The circuit was tested using a 2 Ohm resistor to simulate the air bag load.

An additional apparatus was designed to measure the gas temperature in the bag. It involves injecting a hypodermic needle into the bag during inflation. A prototype device was constructed using a standard 16-gauge medical needle and a 0.001 inch thermocouple. The K-type thermocouple was threaded through a ceramic insulator, which was then mounted in the needle. A 0.0005 inch thermocouple is to be used to provide faster response in the prototype tests.

The cold-flow apparatus was set up to simulate a typical inflator. The design represents a slice of the inflator, scaled down by similitude. High pressure (6000 psig) nitrogen gas is supplied to the scaled-down inflator and controlled by a high pressure regulator and plug valves. A few model inflators with various nozzle sizes were tested to keep a designed pressure of 1000 psig throughout the measurement time. The nozzles are based on the actual inflator design.

Shadowgraph and Schleren images were obtained for the initial stage of the flow visualization. Images of the nitrogen jet from the scaled-down inflator were recorded in time sequence. A He-Ne laser was used to illuminate the jets. In the initial transitional stages, two small jets on each side of the module were observed as overlaid images from two holes, while the larger jet in the middle is from a single hole. Upon reaching steady state, the jet shape was partly spherical followed by a turbulent structure 3 to 5 mm downstream of the nozzle. The image suggests that the flow was an underexpanded jet. Thus, the backpressure was less than the critical pressure and the jet expanded as it discharged from the nozzle. The radial acceleration of the gas and subsequent reverse direction created the spherical wavy structure. A Mach-disc was observed between the spherical and turbulent structures. In the turbulent structure, expansion and compression processes clearly define typical X-shaped waves. A retreating jet was observed just after the valve was closed. The middle jet held a periodic pattern even at the lower stagnation pressure and flow rate.

Based on the information obtained from the model inflator test, a scaled-down canister has been designed. A polycarbonate scaled canister is currently being constructed. The two-piece canister model will be bolted on the model inflator. The design will allow several sizes, shapes and configurations to be tested.

A commercial CFD code (CFD-ACE version 2.2, CFD Research Corporation) was installed and tested to apply a multi-dimensional, time-dependent CFD model to the air bag module aspiration process. A member of the University of Iowa research team participated in a training course offered by CFD Research Corporation. CFD engineers assisted in setting up the grid structure for the aspirating air bag unit.

CFD-ACE is still developing the moving (or sliding, deforming) boundary systems and they are partly available. In CFD-ACE, users have to prescribe the locations of the grid points as a function of time to use the moving boundary conditions. The current facility of the moving boundary conditions is not appropriate to simulate inflating motions of a folded air bag. The movement of the folded air bag depends on the properties of hot gases issuing from the combustion chamber. In addition, using the moving boundary conditions is not economical for three-dimensional geometry because of the numerous grid points associated with computational domain expansion.

Instead of using the moving boundary conditions, adding source terms (momentum resistances) into the momentum equations is being considered. Momentum resistances are typically used to model the effects of physical obstructions within the calculation domain. Some common features that can be simulated with momentum resistances in CFD-ACE are porous media, perforated plates, and screens. This method is being studied carefully to check if it is available for the current research area.

A simplified, full-scale, two-dimensional geometry was used as a first step. The grid distribution is very important for compressible flow, and several types of grid systems were established to solve two-dimensional, unsteady, turbulent, and compressible flow problems.

Several types of grid generation, under-relaxation factor, differencing schemes, and time steps are being tested to produce a well-converged solution. Transient inlet boundary conditions and transient momentum resistances will be used in future models.

Project F. 5: This project was canceled in year 1.

Project F. 6: *Measure Properties of Vehicle Interior Materials*

Physical testing methods will be developed that can rapidly and efficiently characterize the material constitutiveproperties (i.e., relationship between stresses applied and strains induced) of vehicular structures and materials that the occupant can interact with, i.e., composite padding and sheet metal structures within the vehicle interior. A database of the physical properties of these materials will be compiledfor computer models of the interactions between the occupant and the vehicle interior.

Peter C. Chang, Ph.D., of the University of Maryland, is the principal investigator for this project.

The 5/8 inch polycarbonate Hopkinson Bar is being used at the lower end of its capability to test lightweight polyurethane foams. A reservoir pressure of 7 psi is used to propel the striker bar. At lower pressures the striker bar velocity is very erratic. Velocities and strain rates obtained with this pressure setting are much lower than in the earlier testing. A polycarbonate test sample that was originally 0.28 inches thick reduced to 0.25 inches after being hit with the stress wave. This equated to an overall strain of 10%, which is much less than seen in earlier testing with these foams. The velocity of the projectiles is about 19 mph in experiments at this pressure level.

For a constant state of stress in the sample, the transmitted pulse plus the reflected pulse should equal the incident pulse. This was not observed experimentally. The transmitted pulse length is greater than the incident pulse length. The transmitter bar may not be long enough to permit correct recording of the transmitted pulse. It is possible that there are reflections from the end of the transmitter bar occurring during the time that the transmitted pulse is being recorded. The length of the transmitter bar will be increased before additional samples are tested.

The drop weight testing facility is being modified to permit testing of samples of the PU foam in such a way as to obtain velocity decay as a function of distance of travel and impulse level in the samples. This apparatus will subject cylinders of the foam that are approximately two inches in diameter to impact from weights of various densities dropped from various heights. In this way, impacts of identical velocities and varying impulses can be achieved. These tests will utilize electromagnetic coils to measure velocity at both the top and bottom of the cylindrical specimens. In this manner, the magnitude of the energy absorption at different impact velocities can be obtained.

A vertical Split Hopkinson Bar apparatus is being constructed that will use a drop weight to impact the incident bar. The ordered parts have arrived and other elements are being machined. The device will be approximately 20 feet tall with a maximum drop distance of eight feet. This should permit tests at impact velocities between 0 and 15 mph. The diameter of the specimen will be 5/8 inches and the sample will be identical to those used in the current Hopkinson Bar. The only difference will be that the lower impact velocities can be more precisely controlled.

Project F.7: This project was canceled per agreement between NHTSA and GM.

Project F.8: *Development of Thorax Model*

The research effort in the first two years will be continued. The finite element thorax model will be further developed with emphasis on the modeling of the heart and the lungs. The material testing of the human heart, lung, airway, diaphragm and liver will provide the basis for modeling the mechanical behavior andfailure mechanisms of these internal organs. The thorax model under various external loading and impact conditions will also be investigated. The cadaveric impact sub-project will shed light on the thoracic injury mechanisms and provide a basis for validating the thorax model.

Sub-Project F.8 (a): Biomechanical Response and Injury Mechanisms in Lateral Velocity Pulse Impacts

John Cavanaugh, M.D., of Wayne State University, is the principal investigator for this sub-project.

Two BIOSID tests and one cadaver test were conducted with a rigid impactor. The impactor velocity was approximately 12.9 mph and the stroke was approximately 12.6 inches. The results are summarized in the following table:

Test No.	Peak Acceleration (G)					Peak Deflection (in)			V*C (m/s)	Contact Force (kN)
	R1	R2	R3	T1	T12	R1	R2	R3		
BIO 17	141.4	125.6	139.0	16.4	11.9	1.65	1.66	1.70	1.16	4.1
BIO 18	140.6	124.5	139.8	16.1	11.6	1.64	1.63	1.66	1.13	4.0
	R4	R8		T1	T12		R6			
CAD 1	108	141		18.4	29.7		1.83		1.17	2.7

Much shorter contact duration and lower contact force were observed in the cadaver test compared to the BIOSID tests. Although the deflections measured in the cadaver test were approximately 36% higher than the BIOSID.

The autopsy of CAD 1 found right ribs 5 and 6 fractured adjacent to the vertebrae and right ribs 7 and 8 fractured at the anterior axillary line. All other body regions were intact.

Sub-Project F.8 (b): Development of a Finite Element Thorax Model

Yih-Charng Deng, Ph.D, of GM Body Engineering and Integration Research, is the principal investigator for this sub-project.

The thorax model has undergone additional improvement to correlate its impact response to the corridors established from cadaver tests. Specifically, characteristics of the thoracic spine, sterno-costal joints, vertebro-costal joints, and contact definitions between various parts of the model were carefully examined and modeled. To investigate potential numerical difficulties associated with soft tissue-to-soft tissue and soft tissue-to-bone contact, simple numerical models were used to study suitable ways to simulate these contact interactions.

To investigate the model impact response, pendulum impact to the sternum was simulated. The 23.4 kg pendulum was a 6-inch diameter cylinder. Impact speeds of either 4.5 or 6.7 m/s were used. The force-deflection response of the thorax was compared to the cadaver corridors established by Neathery (1974). The model response is in general agreement with the cadaver corridors, although improvements are still needed. The ongoing development of new material models in the DYNA3D and material testing program in Sub-Project F.8 (c) will provide more rigorous theoretical basis and quantitative information for modeling the soft tissue behavior in the thoracic region.

Sub-Project. F.8 (c) Mechanical Properties of Human Heart, Lung, Airway, Diaphragm and Liver for Highway Safety Research.

Michael R. T. Yen, Ph.D., of the University of Memphis, is the principal investigator for this sub-project.

The bi-axial testing machine is a custom instrument designed and produced by E. H. Mead Instruments, specifically for the experiments of this project. Upon completion of the device, two of the project staff went to E. H. Mead Instruments to verify the accuracy of the design and to be trained in the operation of the device. During the training period, two-dimensional experiments using a rubber sheet with a dimension of 4 cm by 4 cm by 0.2 cm were performed. The main type of experiment is stretching the sheet in one direction while the other dimension is kept constant. The measured quantities are the forces in the main and transverse direction and the expansion ratio. With a 486 computer as the central unit, the system demonstrated its capacity to stretch the rubber sheet to the specified range of stretch ratios at various rates, and to collect stress and strain data continuously and automatically. The accuracy of the dimensional measurements was checked by means of a number of equally spaced parallel black lines. The distance between each symmetric pair was measured by a video dimensional analyzer and a best fit linear regression line was obtained. It demonstrated good linearity. Weights up to 500 g were used to calibrate the force measurements. The calibration curve was linear in the broad range from 20 g to 500 g, but there existed significant non-linearity below 20 g. This non-linearity was corrected prior to the device being shipped from the manufacturer.

It is expected that preliminary experiments on sample tissues will begin in the third quarter of year 3.

I.G. Impairment Research

Project G.1: Changes in Crash-Involvement Rates as Drivers Age)

This project will determine how a number of risks vary with driver age from two distinct perspectives. First, how do the risks change that older drivers themselves face--a matter mainly of concern to the older driver. Second, how do the risks change that older drivers impose on other road users--a matter mainly of concern to public bodies. Using the derived relationships, these measures shall be projected into the future using results from population projections.

Leonard Evans, D.Phil., of GM Safety Research, is the principal investigator for this project.

Work is in progress on this project, and any expenditures (including oversight and administrative expenses) during the second quarter of year 3 will be reported in the financial reports submitted to NHTSA after NHTSA has approved the statement of work for year 3.

Various government agencies were contacted to obtain data related to population, drivers and driver licenses. Additional data were obtained from the Documents Library of the University of Michigan, UMTRI, and the Population Studies Center of the University of Michigan.

The following data sets were obtained: (1) FARS 1995, (2) FARS 1996, (3) Transportation Data Sampler-3 1996, (4) Transportation Safety, (5) US Bureau of Census data on population, and (5) limited driver license data from FHWA. The FARS files were formatted.

SAS programs were written to merge the different databases, plot the FARS data, determine the total fatalities in US traffic crashes between 1988 and 1996, and driver fatalities for the same time period. SAS programs were also written to obtain one-way and two-way tables on the FARS variables and to categorize the vehicles involved in these crashes. Crash fatalities were classified according to the type of person and the type of crash.

Subsets of the FARS data generated in SAS were imported into EXCEL for the calculation of statistical parameters. Word and PowerPoint tree charts were generated for some of the tabulated FARS data.

Project G.2: Self-Regulation as a Mechanism for Improving the Safety of Older Drivers

> *Visual processing deficits, including visual sensory impairment, slowed visual processing speed, and visual attention impairment, are associated with increased crash risk in older drivers. This project will conduct an intervention evaluation study to examine whether older drivers with visual processing deficits would avoid the most difficult and challenging driving situations, if made aware of these problems, thereby reducing their crash risk The study will have a pre/post design with random assignment to the treatment and usual care control groups. Subjects in the treatment group will be visually and cognitively assessed and through a carefully structured curriculum, will be educated about how identified impairments could impact driving performance, and how self-regulation could improve their safety. The usual care group will be provided information about visual processing impairment and its ramifications for everyday life, as typically provided by ophthalmologists and optometrists. Approximately 100 to 200 subjects will be enrolledper group. This study could demonstrate that a practical and inexpensive intervention of at-risk older drivers--namely informing them of visual processing limitations, including their ramification for driving, and suggesting ways to promote safety through self-regulation--may lead older drivers to self-regulate driving in such a fashion as to lower crash risk yet preserve mobility. The long-term goal of this research is to assist older drivers in staying on the road as long as it is safely possible for them to do so.*

Cynthia Owsley, Ph.D., of the University of Alabama at Birmingham, is the principal investigator for this project.

The constructs of the theoretical underpinnings to be addressed in the intervention protocol have been identified. Educational strategies to target these constructs have also been defined. These strategies will be incorporated into the topics addressed in the protocol of the first intervention session. These topics include vision impairment associated with aging, the effects of this vision impairment on safe driving, and a focus on the skills of self-regulation. The educational objectives of each topic have been outlined and the media tools needed to communicate each message have been identified.

Educational materials for the intervention have been collected and reviewed. This included a comprehensive review of print and audio-visual materials that addressed the topics of vision impairment and driver safety in the older adult population. The review of educational materials revealed several existing media tools that will be incorporated into the protocol. However, additional media tools are needed to further convey the specific educational message. Therefore, slide and tape productions are being created to address the specific goals and objectives outlined in the project protocol. These media productions will include facts about safe driving and testimony from other older drivers who currently self-regulate their driving. Production will be completed in the third quarter of year 3.

A curriculum manual is being drafted that includes the specific goals and objectives of each topic addressed in the intervention protocol. The script of the intervention sessions is written in detail to ensure that all information is conveyed. This manual will serve as a guide for the interventionist as the educational sessions are conducted. This manual will also assist in the standardization of the one-on-one counseling sessions and will enhance reliability. At the conclusion of the project, these materials will be used to create a curriculum for eye care specialists.

The questionnaires to be used at pre-testing and post-testing assessments have been identified. The primary outcomes of driving exposure, driving avoidance, and driving space will be measured using the existing Driving Habits Questionnaire. Additional questionnaires have been collected to measure secondary outcomes such as increased knowledge of vision and driving safety, increased perceptions of crash risk, and willingness to exercise self-regulatory practices. New instruments were created when exiting questionnaires were unavailable.

The project staff has been trained in all aspects of participant recruitment and administration of screening measures. Training regarding the administration of the pre-testing and post-testing measures and the one-on-one educational sessions is near completion in anticipation of pilot testing.

Upon completion of the educational media, pilot testing of the curriculum will begin. Pilot testing will be conducted with a small sample of older drivers. This process will provide the opportunity to receive feedback on the curriculum and to make the necessary revisions to the existing protocol.

Recruitment materials have been drafted. These materials include the initial contact letter, the participant brochure, and the telephone recruitment scripts. Recruitment sources for pilot testing have been identified.

The Clinical Research Unit will be relocating to larger facilities in December, 1997. These newly renovated facilities will provide space designated solely for the administration of this project.

Project G.-3: Understanding the Influence of Older Driver Disability on Mobility and Quality of Life

A comprehensive survey will be conducted to understand older driver self-regulation measures undertaken and the impact such measures have on the total travel patterns andfeelings of independence and autonomy. The survey methodology will include objective and attitudinal questions, as well as a travel diary. Older drivers will be surveyed and divided into four groups. Participants in three of the groups will receive interventions consisting of one of the following. (1) personalized information from a respected medical professional; (2) self-assessment instruments; or (3) older driver training courses. Participants in the *fourth group will receive no intervention. All participants will be re-surveyed two months and again one year after the intervention to determine if any aspects of the driving task travel decisions or travelpatterns changed. Results will be used to evaluate the effectiveness of the three intervention strategies and to develop programs to improve driver behavior without reducing mobility and independence.*

Sandra Rosenbloom, Ph.D., of the University of Arizona, is the principal investigator for this project.

Efforts were concentrated on the attitudinal survey, although the travel diary was also refined. Three different venues were selected to test the attitudinal survey and 37 questionnaires were administered. At the end of the survey period, the respondents were engaged in detailed discussion of what they thought the individual questions meant and what they themselves had really meant in answering. As a result, seven major questions were dropped from the survey, five were re-phrased, and two new questions were added.

Project G.4: Improvement of Older Driver Safety Through Self-Evaluation

The major aim of this project is to assist older drivers in evaluating their own capabilities, thereby enabling them to make informedjudgments about the kinds of driving they may undertake safely and to enhance theirperformance where possible. A literature review, the convening of a panel of experts, andfocus groups will be used to determine what driving abilities can be reliably self-assessed Assessment procedures will be determined through the literature review, expert panel, andfocus groups. A self-assessment instrument will be developed pilot tested with older drivers, and revised The instrument will then be validated with older drivers in various performance measures. Further instrument revision, field-testing, andfinal completion of the self-assessment instrument will be done. At the end of the project, an instrument will be available for use by older drivers to assess their own driving and to provide a basis for informedjudgments regarding safe driving decisions and/or measures to enhance performance.

Jean Shope, Ph.D., and David Eby of the University of Michigan Transportation Research Institute, are the principal investigators for this project.

The literature review continued throughout the second quarter of year 3. The review of the relationship between medications and driving among older drivers is essentially complete. It will, however, need to be updated periodically. The review covers the prevalence of use, effects on driving ability, and performance assessment regarding benzodiazepines, antihistamines, antidepressants, analgesics, anti-anxiety drugs, and insulin.

The review of dementia and Alzheimer's disease related driving is also essentially complete, except for periodic updates. This review covers disease progression, actual versus perceived driving ability, assessment tools, as well as driving reduction and cessation recommendations.

The review of attention (divided, sustained, selective), memory, problem-solving, and decision-making related to older drivers was roughly three-quarters completed by the end of the second quarter of year 3. Other cognitive areas being covered include field dependence/independence, relevant/irrelevant information, information processing, mental workload, spatial cognition, and consciousness. Emphasis is on areas that can be reliably self-assessed, or assessed with the help of others.

Database searches were conducted to identify research on various measures of visual function, and their relationship to the elderly and driving capability. Relevant terms were identified. Citations and abstracts were located. Emphasis is on areas that can be reliably self-assessed, or assessed with the help of others.

Database searches were conducted to identify research that relates to psychomotor control in older drivers. Relevant terms were identified. Citations and abstracts were located.

A database search was conducted, and relevant articles were retrieved on medical conditions. Topics covered include cardiovascular disease, arrhythmia, stroke, epilepsy, diabetes, sleep apnea, and syncope. Articles and papers are being read and synthesized. The review was approximately three-quarters completed by the end of the second quarter of year 3.

Samples of two existing self-assessment tools were obtained from AARP and AAA Foundation for Traffic Safety. An assessment tool for physician use, produced by the University of Arkansas, was identified.

A preliminary list of expert panel members was identified.

Planning began for focus groups to be conducted in January or February, 1998. Discussion involved where and how to recruit subjects; communication and trust-building that will be needed; and the grouping of subjects according to gender, suburban/rural, and drivers/non-drivers.

Project G.5: Reduction or Cessation of Driving Among Older Drivers

Older drivers are generally reluctant to give up driving, but circumstances, such as deterioration ofphysical and driving abilities and loss of confidence. may cause them to reduce or stop driving. Individuals vary widely and the phenomenon of driving reduction and cessation is not well understood. This research will address why and when older drivers stop driving, the factors that contribute to their decision to reduce or stop driving, and the differences between the genders in the reduction or cessation of driving. The driving cessation process will be explored through a series of focus groups of older drivers who are *still driving and drivers who have stopped driving in the past two years. Findings from the focus group interviews will be used to develop a questionnaire and a list of variables to be assessed. Random samples for a telephone survey will be drawn from appropriate populations in two states which differ in climate conditions. The questionnaire will include questions on past driving experience, crash history, confidence in driving ability, present driving patterns, health status, availability of alternatives for transportation, and other topics relating to driving reduction or cessation. Survey data will be analyzed by gender and to identify relationships between various factors and driving reduction behavior. Focus groups will be conducted to help interpret the survey findings.*

Jean Shope, Ph.D., and Lidia Kostyniuk, of the University of Michigan Transportation Research Institute, are the principal investigators for this project.

The literature review continued throughout the second quarter of year 3. Articles were identified, retrieved, read, and synthesized in an ongoing manner.

The review of mobility and older drivers is essentially complete, except for periodic updates The topics covered include being a passenger, user of public transit, pedestrian, and urban/suburban/rural patterns of relocation and migration.

The review of risk perception was well underway, but less than half completed by the end of the second quarter of year 3. The material covers older drivers' perceptions of risk to themselves, as well as their risk to others. The review of changes in older drivers' vehicle navigation abilities was close to completion.

Planning began for the January and February focus groups. Discussions involved where and how to recruit subjects; communication and trust-building that will be needed; and the grouping of subjects according to gender, suburban/rural, and drivers/non-drivers.

An abstract was submitted for consideration in the "Transportation and the Elderly" topic area for the 1998 meeting of the Institute of Transportation Engineers. The abstract title is "Reduction/Cessation of Driving Among Older Drivers," and is co-authored by L.P. Kostyniuk, J. T. Shope, and D. Trombley.

Project G.6: Projections of Crashes and Casualties Caused by Older Drivers

This project will estimate how many of the future older drivers will still be driving, and how many miles will be driven annually, at each age. The effects of premature driving cessation and estimated health status of future older drivers will be considered. The causal relationship between driving cessation and the health status of future older drivers by age and gender will be projected The influence of "external" factors, such as Intelligent Transportation Systems (ITS) and the availability of alternative transportation, and "internal" factors, such as physical and cognitive impairments, will be estimated.

Patricia S. Hu, of Oak Ridge National Laboratory, is the principal investigator for this project.

Work on this project will not be initiated until a Cooperative Research & Development Agreement (CRADA) has been executed between Lockheed Martin Energy Research Corporation and General Motors Corporation. This agreement must also be approved by the U.S Department of Energy.

Project G. 7: Factors Contributing to Premature Reduction or Cessation of Driving by Older Men and Women

This project will identify the range offactors contributing to driving reduction or cessation by each gender and will explore which of the factors identified are most amenable to remediation through adaptive devices, vehicle design, rehabilitation, exercise and wellness, or education. The project will also examine the potential benefits to be derivedfrom interventions to counteract premature reduction or cessation of driving.

Jane C. Stutts, Ph.D., of the University of North Carolina, is the principal investigator for this project.

During the second quarter of year 3, a review of the literature was completed. Focus groups are being conducted to explore issues related to driving and driving cessation by older men and women. The focus groups are being conducted by FGI, Inc., a Chapel Hill-based marketing and research firm. A number of meetings were held between project staff and Ms. Sally Schatz of FGI to define the goals and objectives of the focus groups and to develop a recruitment screener and moderator's guide. Half of the focus groups are targeting adults ages 65 and older who have either stopped driving within the past two years or who indicate that they may stop driving within the next year or so. The other half are targeting concerned family members of this population of older drivers and former drivers.

An initial set of draft research questions and focus group topics was developed and circulated to six persons who had indicated their willingness to serve on a review panel for the project. They are Jackie Anapolle with the National Mobility Institute in Boston; Jon Burkhardt with Ecosometrics Inc., in Bethesda; John Eberhard with NHTSA; Linda Hunt with the Occupational Therapy Program at Maryville University in St. Louis; Sandra Rosenbloom with the Drachman Institute in Tucson; and Jean Shope with the University of Michigan Transportation Research Institute in Ann Arbor. Several additional contacts were made to other individuals including Phil LaPoor with the New York State Office for the Aging and Nina Glasgow at Cornell University. Both individuals have been involved in similar research efforts and are expected to provide helpful insights to the present study.

Drawing from the feedback received from the panelists, a revised moderator's guide was finalized and tested in two initial focus groups held in Raleigh, North Carolina, on September 29, 1997. The process of recruiting participants for the two focus groups was enlightening and indicative of the importance of driving in the lives of the elderly. There was essentially no problem in recruiting children who have an interest in a parent's decision to continue or discontinue driving. However, few if any current ôlder drivers were willing to admit that they might no longer be driving in the next year or two. This was true even for those with debilitating visual losses, or those who had recently been found at fault in serious car crashes. As a result, some modifications were necessary to the recruitment screener questions, and the ongoing recruitment process is being closely monitored for the remaining focus groups to help ensure that the target population of older drivers who are on the verge of a decision regarding stopping driving is reached.

Notwithstanding, the initial two focus groups (one with older drivers and former drivers, the other with concerned family members of older drivers and former drivers) were highly successful. One clear outcome of the older driver group was the lack of planning for any future time when driving one's own automobile might not be possible. One 88-year old woman asserted, "I'll cross that bridge when I come to it." From the concerned family members of older drivers, a variety of approaches that might be used to help older drivers make appropriate driving decisions was obtained. Most important, the "children" of older drivers (most in their 50's or 60's themselves) emphasized that their parents needed to feel responsible for making these decisions themselves, and that they as children were handicapped in facilitating this decision, due to the complexities of parent-child relationships that persist even into advanced age.
Focus groups were scheduled during the third quarter of year 3 in Boston, Massachusetts, on October 23; in Phoenix, Arizona, on October 29; in Seattle, Washington, on October 31; and in St. Louis, Missouri, on November 3.

Project G. 8: Investigations of Crashes and Casualties Associated With Older Drivers

> *This project will systematically examine the at-fault crashes and related injuries associated with older drivers using a variety of data sources over a ten-year historical time period. The analysis will use detailed crash data from North Carolina. FARS and GES (General Estimates System) data will also be utilized to contrast the findings from North Carolina with those seen nationally, This project will also analyze data in the North Carolina driver history file to examine cumulative crash and violation records of a sample of drivers 65 and older with a comparison of drivers age 45 to 64 to further examine at-fault crash involvement rates over a four-year period*

Donald W. Reinfurt, Ph.D., of the University of North Carolina, is the principal investigator for this project.

The task of setting up and testing the driver history and crash data study files is nearly completed.

The driver history study file for all drivers aged 45 and older (65 and older as the study group and 45 to 64 as a comparison group) for the four-year period of 1992 through 1995 has been pulled and examined. There are a total of 2.663 million drivers in this file, with 926,978 drivers in the study group, 381,742 of whom are aged 75 and older. Overall, 90.9% have no violations over this period while 7.3% have one violation and 1.8% with two or more violations. Speeding violations (6.4%) leads the list, followed by alcohol (0.73%). The crashes being studied occurred between 1987 and 1996, inclusive.

Project G.9: Remediation Through Adaptive Equipment and Training

- *Focus groups, interviews, and surveys will be used to determine if older individuals stop driving because they are not informed that adaptive driving equipment may prolong independent mobility. Older individuals who either question their ability to continue driving or have recently quit driving because they could not physically operate their vehicles will be recruited. An occupational therapist will evaluate andprescribe adaptive equipment and an experienced driving instructor will train the individuals to safely use the equipment. Follow-up surveys will be conducted to determine the influences of adaptive driving equipment on social, psychological, physical and economic factors. Crash data will also be examined.*

Linda Hunt of Maryville College, St. Louis, Missouri, is the principal investigator for this project.

Subjects were first seen on June 25, 1997. Eleven subjects agreed to participate in the driving study from June through September. Of those eleven, one canceled prior to the evaluation and one subject was a "pilot" subject. From the pilot subject experience, additional necessary questions were added to the survey, the time burden of the subjects' commitments was assessed, and the procedures were refined. The remaining subjects fell into two categories after their evaluation: (a) those who were not safe to drive under any circumstances, and (b) those who might benefit from training and/or adaptive equipment. All subjects completed the assessment protocol without hardship, accident, or unusual circumstances.

As a result of the initial evaluation, two of the subjects were found to be unsafe drivers. Lessons and/or adaptive equipment would not improve their driving capabilities. Therefore, these individuals were told not to drive and letters were sent to their physicians stating the results of the evaluation. Both of these individuals had been instructed by their physician to undergo the driving evaluation prior to trying to drive again.

Another two subjects underwent driving lessons after the initial evaluation but after one or two lessons were determined to be unsafe to drive. These individuals were also told not to drive and the physicians associated with these subjects were notified of the results.

Factors contributing to untrainable drivers included: denial of problems; inattention causing missed "Stop" signs and poor lane usage; and a disregard for others on the road resulting in failure to yield the right-of-way when turning, changing lanes, or merging into traffic.

Four of the subjects are currently taking lessons or have recently completed their training. The remaining subject became ill shortly after the evaluation, but is now ready to start his training. Factors which require intensive driver's training include: upper extremity weakness, loss of confidence, limited use of lower extremities, and overall low endurance.

Demographics of the nine subjects are given in the following table:

RSex:	8 maCaucasfenAfrican-American
Age:	youngest age = 72, oldest age = 83
Marital status:	4 married, 5 widowed
Education:	2 less than high school, 3 high school graduates, 2 some college, 1 college graduate, 1 graduate degree
Subject Diagnoses:	cerebral vascular accident, cardiac problems, diabetes, paralysis from a blood clot, head injury

Eight new subjects are scheduled for evaluation in October, and two more are scheduled for November.

Recruitment announcements have been placed in two small local newspapers that have a large older adult reading audience. In-services have been presented to social workers. Additional in-services are scheduled for November at older adult health fairs.

The research program has moved from Washington University to Maryville University with a minimum of disruption to the project. The facility at Maryville University is more accessible to subject's physical needs. There is little walking required to reach the lab and there are no stairs.

A Humphrey Visual Field Analyzer has been leased. Most of the subjects have had strokes and their visual fields may be damaged. Also, as people age, their visual field narrows. A methodology for identifying visual field deficits has been developed.

DOT/GM Settlement Agreement
Summary Report of Expenditures
April 1, 1995 - September 30, 1997

(Year Three Second Quarter)

		Actuals									
		Years 1 & 2 (a)	Cumulative April - June	July 1997	August 1997	September 1997	Second Quarter Year 3 (b)	Year 3 to Date Total (b)	Expenditures Through September 1997	Required Expenditures by End of Year 3	(Over) / Under (c)
		$	$	$	$	$	$	$	$	$	$
B	Fire Safety Research	5,092,676	41,864	12,235	562,483	(35,559)	539,159	581,023	5,673,699	5,000,000 (d)	(673,699)
C	Public Education	4,985,000	-	400,000	165,000	10,000	575,000	575,000	5,560,000	7,113,000	1,553,000
D	Crash Test Dummy Research & Development	2,049,939	-	149,645	41,939	26,096	217,680	217,680	2,267,619	3,500,000	1,232,381
E	Burn & Trauma Research	2,220,991	-	-	-	11,290	11,290	11,290	2,232,281	3,000,000	767,719
F	Computer Modeling	2,279,575	-	-	282,503	60,352	342,855	342,855	2,622,430	2,000,000 (e)	(622,430)
G	Impairment Research	1,576,351	-	-	-	-	-	-	1,576,351	2,600,000	1,023,649
H	Child Safety Seats	6,000,000	2,000,000	-	-	-	-	2,000,000	8,000,000	8,000,000	-
	Total Expenditures	24,204,532	2,041,864	561,880	1,051,925	72,179	1,685,984	3,727,848	27,932,380	31,213,000	3,280,620

Notes:
(a) Years 1 & 2 represent April 1, 1995 - March 31, 1997.
(b) Year 3 represents April 1, 1997 - March 31, 1998.
(c) Over spending to date, or additional spending required by end of Year 3.
(d) Additional expenditures of $5 million are required in years 3-5.
(e) Additional expenditures of $3 million are required in years 2-4.

DOT/GM Settlement Agreement
Report of Expenditures
April 1, 1997 - September 30, 1997
"B" Fire Safety Research
(Year Three Second Quarter)

	Projects	Cumulative April - June $	Actuals July $	Actuals August $	Actuals September $	Second Quarter Total $	Year 3 to Date Total (a) $	Year Budg $
B 1	Analysis of Motor Vehicle Accident Data	-	- (b)	- (b)	- (b)	-	-	5
B 2	Case Studies of Motor Vehicle Fires	2,790	186	434	310	930	3,720	7
B 3	Fire Initiation and Propagation Tests	-	- (b)	432,557 (e)	(65,771) (f)	366,786	366,786	2,1
B 4	Evaluation of Potential Fire Intervention Materials & Technologies	24,578	11,623	23,356	6,044	41,023	65,601	4
B 5	Development of Crash Test Protocols	-	- (b)	1,426 (e)	2,976	4,402	4,402	5
B 6	Analyses of Failure Modes & Effects for Alternatively Fueled Vehicles	248	-	-	-	-	248	
B 7	Development of Criteria & Methodologies for In-Service Inspections of Gaseous Fuel Pressure Vessels	-	-	-	-	-	-	
B 8	Search of Scientific Literature	14,248	426 (c) (d)	62 (d)	124 (d)	612	14,860	
B 9	Inspection of Aging Vehicles and Testing of Components	-	- (b)	- (b)	- (b)	-	-	1(
B 10	Study of Flammability of Materials	-	- (b)	104,648 (e)	20,758	125,406	125,406	5
B 11	Study of Component Influence on Vehicle Fires	-	-	- (b)	- (b)	-	-	2
B 12	Canceled per agreement between NHTSA and GM	-	-	-	-	-	-	
B 13	Development of Technical Information for Dissemination to First Responders	-	-	-	-	-	-	2(
B 14	Demonstration of Enhanced Fire Safety Technology	-	-	-	-	-	-	3(
B 15	Theoretical & Experimental Study of Thermal Barriers Separating Automobile Engine & Passenger Compartment	-	-	-	-	-	-	
	Total Expenditures	41,864	12,235	562,483	(35,559)	539,159	581,023	5,63

Notes:

(a) Year 3 represents April 1, 1997 - March 31, 1998.

(b) Work is progressing on this project and any expenditures (including oversight and administrative expenses) will be reported upon NHTSA's approval of the Statement of Work for Year 3.

(c) Although the substantive work of this project was completed in Year 2, some expenditures toward the end of Year 2 are being reported in Year 3.

(d) Although the substantive work of this project was completed in Year 2, there were expenditures in Year 3 for oversight or administrative work.

(e) This amount includes earlier expenditures on this project, which occurred prior to NHTSA's approval of the Statement of Work.

(f) A refund check for $131,000 was received by GM from NIST as a result of a reduction in the functions being performed by NIST in this project.

(g) Budget period for Project B 15 is for Years 2 and 3, but the initial budget of $50,000 was fully expended in Year 2. As of September 30, 1997, there is no budget for expenditures in Year 3.

DOT/GM Settlement Agreement
Report of Expenditures
April 1, 1997 - September 30, 1997
"C" Public Education
(Year Three Second Quarter)

Projects	Actuals: Cumulative April - June	Actuals: July	Actuals: August	Actuals: September	Actuals: Second Quarter Total	Actuals: Year 3 To Date Total (a)	Year 3 Budget	Year 3 Actual (Over) / Under Budget
	$	$	$	$	$	$	$	$
C 1 Support for State Safety Legislation	-	-	-	-	-	-	560,000	560,000
C 2 Support for Enforcement of State Safety Laws	-	-	135,000	-	135,000	135,000	1,840,000	1,705,000
C 3 Support for Safety Organizations	-	400,000	30,000	10,000	440,000	440,000	600,000	160,000
Total Expenditures	-	400,000	165,000	10,000	575,000	575,000	3,000,000	2,425,000

Notes:
(a) Year 3 represents April 1, 1997 - March 31, 1998.

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Report of Expenditures
April 1, 1997 - September 30, 1997
"D" Crash Test Dummy Research & Development
(Year Three Second Quarter)

Projects	Actuals: Cumulative April - June $	July $	August $	September $	Second Quarter Total $	Year 3 To Date Total (a) $	Year 3 Budget $	Year 3 Actual (Over) / Under Budget $
D 1 Development of High-Speed Deflection Sensor for the Hybrid III Dummy Familiy	-	31,100 (b)	11,589	7,753	50,442	50,442	100,000	49,558
D 2 Development of Reusable, Rate-Sensitive	-	91,720 (b)	20,867	12,496	125,083	125,083	300,000	174,917
D 3 Refinement of Crash Test Dummy Necks	-	26,825 (b)	9,483	5,847	42,155	42,155	305,000	262,845
D 4 Identification of Injury Mechanisms Resulting in Injuries to Upper Extremities in Frontal Crashes	-	- (c)	- (c)	- (c)	-	-	- (d)	-
D 5 Investigation of Alternative Data Compression / Transmission Methodologies	-	- (c)	(c)	(c)			- (d)	-
D 6 Cancelled per agreement between NHTSA and GM	-	-					-	-
D 7 Development and Dynamic Testing of a Second-Generation Pregnant Abdomen	-	- (c)	- (c)	- (c)	-	-	- (d)	-
D 8 Data Acquisition for Development of a Uteroplacental Interface for the Second-Generation Pregnant Abdomen	-	- (c)	- (c)	- (c)	-	-	- (d)	-
D 9 Investigations of Pregnancy Loss Resulting from Motor Vehicle Crashes	-	- (c)	- (c)	- (c)	-	-	- (d)	-
D 10 Seated Anthropometry During Pregnancy	-	- (c)	(c)	(c)			- (d)	-
D 11 Biofidelity of the Hybrid III Lumbar Spine	-	- (c)	(c)	(c)			- (d)	-
D12 Development of Estimated Infant Head Injury Tolerances	-	-	-	-			- (d)	-
D13 Dummy Enhancements for Occupant Position Sensor Compatibility	-	-	-	-			- (d)	-
Total Expenditures	-	149,645	41,939	26,096	217,680	217,680	705,000	487,320

Notes:
(a) Year 3 represents April 1, 1997 - March 31, 1998.
(b) This amount includes earlier expenditures on this project, which occurred prior to NHTSA's approval of the Statement of Work.
(c) Work is progressing on this project, and any expenditures (including oversight and administrative expenses) will be reported upon NHTSA's approval of the Statement of Work for Year 3.
(d) A project description for Year 3 had not been submitted to NHTSA as of September 30, 1997

DOT/GM Settlement Agreement

Report of Expenditures

April 1, 1997 - September 30, 1997

"E" Burn & Trauma Research

(Year Three Second Quarter)

Projects	Actuals: Cumulative April - June	July	August	September	Second Quarter Total	Year 3 To Date Total (a)	Years 3-4 Budget	Years 3-4 Actual (Over) / Under Budget
	$	$	$	$	$	$	$	$
E 1 Fund Data Collection On Crashes, Injuries, and Their Consequences	-	-	-	-	-	-	1,800,000	1,800,000
E 2 *Fund Research in Burn & Impact Trauma* Mechanisms and Treatment	-	-	-	-	-	-	200,000	200,000
E 3 Establish a Network for Data Collection on Crashes, Injuries, and Their Consequences	-	- (b)	- (b)	11,290 (c)	11,290	11,290	780,000	768,710
Total Expenditures	-	-	-	11,290	11,290	11,290	2,780,000	2,768,710

Notes:

(a) Year 3 represents April 1, 1997 - March 31, 1998.

(b) Work is progressing on this project, and any expenditures (including oversight and administrative expenses) will be reported upon NHTSA's approval of the Statement of Work for Year 3.

(c) This amount includes earlier expenditures on this project, which occurred prior to NHTSA's approval of the project.

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Report of Expenditures

April 1, 1997 - September 30, 1997

"F" Computer Modeling

(Year Three Second Quarter)

Projects	Actuals: Cumulative April - June	July	August	September	Second Quarter Total	Year 3 To Date Total (a)	Years 3-4 Budget	Years 3-4 Actual (Over) / Under Budget
	$	$	$	$	$	$	$	$
F 1 Further Development of Head/Brain Model	-	- (b)	67,084 (c)	14,384	81,468	81,468	150,000	68,532
F 2 Development of Head/Neck Models	-	- (b)	50,156 (c)	10,980	61,136	61,136	650,000	588,864
F 3 Develop Interactive Computer Software for Characterization of the Hazards Posed by Heat and Exposure to Toxic Agents Associated with Fire	-	- (b)	76,233 (c)	16,368	92,601	92,601	460,000	367,399
F 4 Experimental and Analytical Study of Transient Heat Loss to Air Bag Materials	-	- (b)	33,122 (c)	9,328	42,450	42,450	890,000	847,550
F 5 Canceled per agreement between NHTSA & GM	-	-	-	-	-	-	-	
F 6 Measure Properties of Vehicle Interior Materials	-	- (b)	- (b)	-	-	-	20,000	20,000
F 7 Canceled per agreement between NHTSA & GM	-	-	-	-	-	-	-	
F 8 Development of Thorax Model	-	- (b)	55,908 (c)	9,292	65,200	65,200		484,800
Total Expenditures	-	-	282,503	60,352	342,855	342,855	2,720,000	2,377,145

Notes:

(a) Year 3 represents April 1, 1997 - March 31, 1998.

(b) Work is progressing on this project, and the expenditures will be reported upon NHTSA's approval of a Statement of Work for Year 3.

(c) This amount includes earlier expenditures on this project, which occurred prior to NHTSA's approval of the Statement of Work.

DOT/GM Settlement Agreement

Report of Expenditures

April 1, 1997 - September 30, 1997

"G" Impairment Research

(Year Three Second Quarter)

Projects	Actuals: Cumulative April - June	Actuals: July	Actuals: August	Actuals: September	Second Quarter Total	Year 3 To Date Total (a)	Year 3 Budget	Year 3 Actual (Over) / Under Budget
	$	$	$	$	$	$	$	$
G 1 Changes in Crash-Involvement Rates as Drivers Age	-	- (b)	- (b)	- (b)	-	-		
G 2 Self-Regulation as a Mechanism for Improving the Safety of Older Drivers		(b)	(b)					
G 3 Understanding the Influence of Older Driver Disability on Mobility and Quality of Life		(b)	(b)					
G 4 Improvement of Older Driver Safety Through Self-Evaluation		(b)	(b)					
G 5 Reduction or Cessation of Driving Among Older Drivers		(b)	(b)					
G 6 Projections of Crashes and Casualties Caused by Older Drivers		(b)	(b)	- (b)				
G 7 Factors Contributing to Premature Reduction or Cessation of Driving by Older Men and Women		(b)	(b)					
G 8 Investigations of Crashes and Casualties Associated with Older Drivers		- (b)	- (b)					
G 9 Remediation Through Adaptive Equipment and Training		(b)	(b)					
Total Expenditures	-	-	-	-	-			

Notes:

(a) Year 3 represents April 1, 1997 - March 31, 1998.

(b) Work is progressing on this project, and any expenditures (including oversight and administrative expenses) will be reported upon NHTSA's approval of the Statement of Work for Year 3.

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Report of Expenditures
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"H" Child Safety Seats

(Year Three Second Quarter)

	Actuals							Year 3 Actual
	Cumulative April - June	July	August	September	Second Quarter Total	Year 3 To Date Total (a)	Year 3 Budget	(Over) / Under Budget
	$	$	$	$	$	$	$	$
H Child Safety Seats								
National Easter Seal Society	400,000					400,000	400,000	
National SAFE KIDS Campaign	500,000					500,000	200,000	
The Safe America Foundation / Operation Baby Buckle	500,000					500,000	500,000	
National Association of Children's Hospitals & Related Institutions	600,000					600,000	600,000	
Total Expenditures	2000,000					2,000,000	2,000,000	

Notes:
(a) Year 3 represents April 1, 1997 - March 31, 1998.